JAN 4 1938

VOLUME 65 [W. B. No. 1217] NUMBER 9

MONTHLY WEATHER REVIEW

SEPTEMBER 1937

CONTENTS

	Page
On Some Properties of the Water-Vapor Spectrum and Their Relations to Atmospheric Radiation. (1 Fig.) W. M. Elsasser	323
On Pilot Balloons and Sources of Light for High Altitude Upper-Wind Observations. (4 Figs.) William H. Wenstrom	326
Tropical Disturbances on the North Atlantic Ocean and the Gulf of Mexico, September 1937. (1 Fig.) Willis E. Hurd	332
Notes and Reviews: Note on H. C. Huang's Investigations of Frontogenesis in the North Pacific. (2 Figs.) Pat. J. Harney	335
Monthly Observed Sunspot Relative Numbers for the Period 1920–1936. (1 Fig.) Charles M. Lennahan	338
Horace R. Byers. Synoptic and Aeronautical Meteorology. *(Review.)* Edgar W. Woolard	338
Bibliography	338
Solar Observations	340
Aerological Observations	343
Rivers and Floods	347
Weather on the Atlantic and Pacific Oceans	347
Climatological Tables	352
Charts I–IX.	

UNITED STATES DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

WASHINGTON, D. C.

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - - - - - - - - - See page 4 of cover for prices

CORRECTION

Volume 65, June, July, and August 1937, pages 257, 287, and 320, respectively: The pressure values are simply *mean monthly station* and *sea-level* pressures *not* reduced to a 24-hour mean. See corrected values in table 3A of this issue (p. 356).

DEPOSITED BY THE
UNITED STATES OF AMERICA
DEC 29 1937

MONTHLY WEATHER REVIEW

Editor, EDGAR W. WOOLARD

VOL. 65, NO. 9
W. B. NO. 1217

SEPTEMBER 1937

CLOSED NOVEMBER 3, 1937
ISSUED DECEMBER 10, 1937

ON SOME PROPERTIES OF THE WATER-VAPOR SPECTRUM AND THEIR RELATIONS TO ATMOSPHERIC RADIATION

By W. M. ELSASSER

[California Institute of Technology, Pasadena, Calif., July 1937]

Measurements of the absorption coefficients of water vapor in the far infrared region have been made by several investigators (**1, 2, 3**). When Simpson first pointed out (**4**) that the transparency interval around wavelength 10μ is of fundamental importance for the heat balance of the atmosphere, a number of important results followed (**5, 6**). The existing data on the absorption coefficients are in rather pronounced disagreement with one another. In a recent paper by H. Wexler (**7**), comparative curves are given which show that the values obtained by Hettner (**1**) in steam are almost everywhere much larger than the values of Weber and Randall (**3**) for moist air at room temperature. An explanation of this discrepancy will be given later. It will be shown that the values of Weber and Randall are probably rather close to the true values of the absorption coefficient in the lower layers of the atmosphere, whereas a decrease with decreasing pressure can be expected. The results of Fowle (**2**) exhibit particularly distinct deviations from Beer's law of proportionality between absorption coefficient and total mass of absorbing material present. These effects must be attributed to the character of the water vapor spectrum as a line spectrum and would not appear in a truly continuous absorption spectrum.

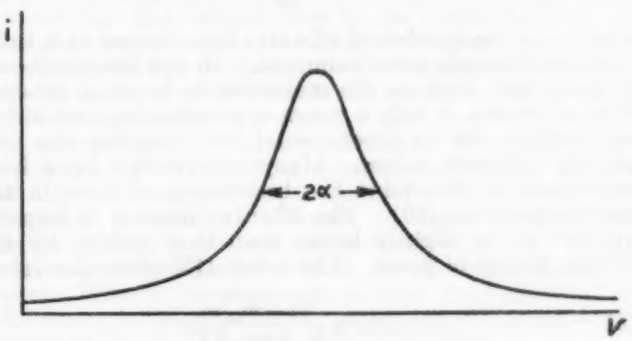
In the present paper we investigate the physical consequences of the fact that the water vapor spectrum in the far infrared consists of a large number of narrow lines. It will be shown that the average width of these lines is much smaller than intervals which could be resolved with the spectrographs used hitherto. For thick layers of vapor complete absorption is nevertheless reached in most parts of the spectrum. It can be shown that under such circumstances the total absorption is approximately proportional to the air pressure in the absorbing layers and is inversely proportional to the square root of the absolute temperature. There is an additional variation with temperature of a more complex type which cannot yet be quantitatively evaluated from the available measurements, but it is probably not very large.

It seems certain that entirely reliable computations of the energy transfer through the atmosphere can only be made when more detailed measurements of the far infrared part of the water vapor spectrum are available. However, the results of the present paper may serve to apply reductions to measurements in order to account for pressure and temperature variations even if the measurements have not the full precision desired.

Before entering into our subject we might remark that in recent years considerable progress has been achieved in our knowledge of the water molecule and the origin of its spectrum, mostly by the work of R. Mecke and his pupils (**8**). They have analyzed almost all of the water vapor bands in the near infrared, from the visible wavelengths up to the band at $.6\mu$. The farther infrared beyond 10μ has not yet been analyzed, principally because of the insufficient resolution of the measurements. For meteorological purposes in particular, the detailed analysis of the near infrared spectrum is of only minor importance; a detailed knowledge of the far infrared spectrum would be rather useful, as will be seen later.

LINE STRUCTURE. PRESSURE AND TEMPERATURE DEPENDENCE

The measurements, as well as the quantum theory of the water molecule, prove that the water vapor spectrum consists of a large number of very narrow spectral lines. We need a formula which gives the intensity distribution in a spectral line, i. e. the absorption coefficient as a function of the wavelength or frequency of the radiation. This distribution depends upon various conditions, such as pressure and temperature. A general theorem states that the total intensity, i. e. the absorption coefficient integrated over the line is a constant characteristic of the line. We therefore introduce a relative intensity i in such a way that the integrated intensity becomes unity. In order to obtain the true spectral absorption coefficient, we have only to multiply i by the total intensity of the line. As is shown in radiation theory (**9**), the intensity distribution is given by the *dispersion formula* (see figure):



$$i(\nu)=\frac{1}{\pi}\cdot\frac{\alpha}{(\nu-\nu_0)^2+\alpha^2} \tag{1}$$

where ν is the frequency, ν_0 the frequency in the middle of the line and α a constant. The dependence of the line

shape upon physical conditions will appear in a variation of α. One verifies readily that $\int i d\nu = 1$. The limits of integration should be 0 and ∞, but since the integrand is already extremely small at $\nu = 0$, one may extend the integration from $-\infty$ to $+\infty$. The maximum intensity which obtains at the line center is evidently

$$i(\nu_0) = \frac{1}{\pi\alpha} \tag{2}$$

For $\nu - \nu_0 = \pm\alpha$ the intensity is half of the maximum intensity (2); therefore the quantity 2α represents the so-called half-width of the line in frequency measure. At great distances from the line center on the other hand, we may simplify (1) to

$$i(\nu) = \frac{1}{\pi} \cdot \frac{\alpha}{(\nu - \nu_0)^2} \tag{3}$$

The intensity is then smaller by a factor $\alpha^2/(\nu - \nu_0)^2$ than the maximum value (2). These parts of the spectral line will be called the "edges" of the line, whereas the part where the intensity is comparable to the maximum intensity will be called the "core" of the line. A spectral line has in principle an infinite extension; in a spectrum with many lines we shall only consider the absorption of one line up to a point where the absorption due to a subsequent line becomes larger than that due to the line in question. From (2) and (3) we see that the narrower a line—i. e., the smaller α—the larger is the intensity in the core and the smaller the intensity in the edges.

We have now to find out what determines the factor α. Radiation theory shows that a spectral line is never infinitely sharp, but the broadening of the lines due to electromagnetic causes is usually excessively small. Under the conditions realized in the atmosphere, line broadening is almost exclusively due to the perturbation of the radiating molecule by collisions with other gas molecules (**10**). As was first shown by H. A. Lorentz (**11**), the molecular impacts interrupt the coherence of the wave train emitted by the radiating system and thus give rise to a broadening of the line. A more rigorous theory has been developed by Dennison (**12**) which will, however, not be needed for our present purpose, since the results do not differ greatly from those of the more elementary Lorentz theory. The constant α is found to be equal to

$$\alpha = \frac{n}{2\pi} \tag{4}$$

where n is the number of effective impacts per unit time. This result needs some comment. In the kinetic theory of gases one assumes the molecules to be rigid spheres. This, of course, is only a rough approximation and different methods for the experimental determination of n give slightly different values. Many experiments have been performed to determine the broadening of lines in the visible spectrum (**10**). The effective number of impacts appears to be slightly larger than that yielded by the kinetic theory of gases. The latter (**13**) gives the value:

$$\alpha = N_0 \sigma^2 p \sqrt{\frac{1 + m_w/m_a}{2\pi m_w R T}} \tag{5}$$

where N_0 is Avogadro's number, m_w and m_a the molecular weights of water and air respectively, R the gas constant, and σ the effective diameter for an impact between a water and an air molecule. This formula is derived under the assumption that the partial pressure of water vapor is small compared to the air pressure. The value of σ is not known with great precision; we may put to sufficient approximation $\sigma = 3.10^{-8}$ cm. Inserting numerical values in (5), we have

$$\alpha = 1.4 \times 10^7 \frac{p}{\sqrt{T}} \tag{6}$$

where p is expressed in *millibars* and T in degrees absolute. From this we can easily calculate the half-width of the lines in the wavelength scale. Since $\lambda = c/\nu$, we have $\Delta\lambda = \Delta\nu . \lambda^2/c$. Now taking $\Delta\nu = 2\alpha$ we obtain for the half-width at standard temperature and pressure

$$\Delta\lambda = 5.8 \times 10^{-4} \left(\frac{\lambda}{10}\right)^2 \tag{7}$$

where λ and $\Delta\lambda$ are expressed in μ. This formula shows that the half-width in the spectral interval which interests us is extremely small. In the measurements of Weber and Randall (**3**), for instance, the slit width of the spectrograph corresponds to an interval of about 0.04μ around a wavelength of 10μ and to a larger interval for greater wavelength. Although the value (7) may deviate slightly from the true width, due to the uncertainty in the molecular diameter σ, it results from an inspection of Weber and Randall's curves that the line width is small compared with the average distance of the lines. In the spectral interval between 12μ and 22μ the experimental curves show about 50 distinctly perceptible lines, thus an average line distance of 0.2μ. For the absorption band around 6μ the measurements of Plyler and Sleator (**14**) indicate a number of about 60 lines in the spectral interval from 5.7μ to 6.7μ, whereas formula (7) yields a line width of only $2.10^{-4}\mu$. The experiments show that with the exception of the gap around 10μ the absorption in sufficiently thick layers of water vapor is practically continuous. We may therefore conclude that the main part of the absorption in thick layers takes place in the edges of the lines. Since according to (3) the absorption coefficient decreases as the inverse square of the distance from the line center, the absorption in the core must be very intense. In thin layers the absorption will take place in the cores only, and since complete absorption there will already be reached in a very thin layer, we may expect for a certain interval of thickness to have absorption of a definite fraction of the primary radiation, this fraction varying only slowly with thickness. This is just what was observed by Fowle (**2**) for a path of about 100 m in atmospheric air and for the spectral region beyond 10μ. For computation of atmospheric transmission on the other hand one usually divides the atmosphere into layers of 1 km thickness and for such thicknesses the absorption may approximately be treated as semicontinuous in the manner of Simpson. We consider now especially this case. We divide the whole of the spectrum where continuous absorption takes place in a sum of intervals belonging to the line cores and in remaining intervals belonging to the line edges. We may for instance define as "core" everything that lies within a distance of 2α from the line center. Since within the cores the absorption coefficient is very large, a "black" radiation flux will be established within these intervals. Now it is well known that, for a black atmosphere, the radiative transmission does not depend upon the absolute value of the absorption coefficient, but only upon the temperature gradient dT/dz. We have assumed that our layer is so thick that complete absorption takes place even in the edges of the lines. Therefore the radiative transmission of our layer *per unit spectral interval* will be of the same order of magnitude for the core intervals as for the edge intervals. Since the core intervals cover only a very

small fraction of the spectrum, we may, in a first approximation, neglect altogether the transmission in the cores. The absorption in the edges is by (3) proportional to α and according to (5) or (6) this means that *the absorption coefficient is proportional to the air pressure and inversely proportional to the square root of the absolute temperature.*

It is evident from the way this result has been derived that it should not be used for calculating the fraction of light absorbed in a moderately thin layer. Such a calculation would yield a much more complicated function. In computations of atmospheric radiation we are interested in certain critical thicknesses; for instance all layers of smaller thickness than a critical one will be considered as transparent and all layers larger than a critical thickness will be considered as black. Other circumstances being the same, the critical thickness is proportional to the air pressure.

This result cannot be checked by the available measurements on water vapor. However Kussmann (**15**) has performed measurements on the infrared spectrum of HCl in the spectral region around 100μ; since the HCl and the H_2O molecules have a closely analogous structure, these results might partly also apply to water vapor. Kussmann investigates the absorption for various partial pressures of HCl in the presence of various foreign gases (CO_2, N_2, A, H_2). He finds that for a given partial pressure of HCl his results can be represented by assuming the absorption coefficient as a linear function $a+bp$ of the pressure p of the foreign gas. The results of Kussmann cannot be interpreted in a very simple way. According to formula (6) the line width is much larger in this spectral region and this is only partly compensated by the reduced pressure. It is possible that the effect of the cores cannot be neglected in this case. The dependence upon the pressure of the foreign gas is the stronger the smaller the partial pressure of the HCl. If we are allowed to extrapolate for a very small partial pressure of HCl, we obtain approximate proportionality of the absorption coefficient with total pressure in a rather large pressure interval. It is, however, doubtful whether this corresponds to the conditions of water vapor in the atmosphere, since nothing is known about the degree of absorption in the cores for HCl.

OTHER EFFECTS

While the results of the preceding section can easily be applied to reduce the absorption coefficient according to changes in pressure and temperature, there exist a number of minor effects of a more complicated nature which shall be briefly reviewed here.

A first question concerns effects of line broadening other than the one discussed above (**10**). One cause of line broadening is to be found in the fact that the molecules are in movement while emitting light; this results in a shift in frequency of the emitted light (Doppler shift). In the average over all velocities and directions of the molecules a broadening of the line appears. This effect is independent of the pressure and directly proportional to the square root of the absolute temperature. A numerical calculation shows that for atmospheric temperatures the line width thus generated is equal to the width (6) if the latter is taken for a pressure of about one-tenth atmosphere. Thus in the troposphere the considered effect is negligible, while in the higher levels of the stratosphere the formulae of the previous section become invalid.

Formula (5) refers to a case where there are many more air than water molecules. For an atmosphere of pure steam, the constant m_A would have to be replaced by m_W. Experiments show that in this case a stronger broadening is to be expected, i. e. molecules of the same kind produce a larger perturbation of a radiating molecule than molecules of a different kind. This effect is very general (**10**). It can be taken into account in formula (5) by assuming a larger effective diameter σ for an impact between two water molecules than for one between a water and an air molecule. This effect combined with the temperature dependence of the total line intensities to be considered in a moment is the cause of the larger absorption coefficients observed by Hettner (**1**) in steam as compared with Weber and Randall's values in moist air (see **7**). It is therefore not advisable to use absorption coefficients of steam for computations of atmospheric radiation, the errors introduced by them being quite appreciable.

H. Becker (**16**) has measured directly the width of absorption lines of HCl in the near infrared at 1.7μ. His values for the half width are about ten times larger than those calculated by formula (7). By the reasons just explained and by some others which we cannot give in detail here, it may rather definitely be assumed that the line widths for water under atmospheric conditions are smaller and much closer to the values derived from the kinetic theory of gases. The considerations of the previous section would of course remain valid even with considerably increased line width, since the mutual distance of the lines is in most parts of the spectrum so much larger than the width.

All the effects discussed so far refer to a change in the shape of a spectral line, the total intensity of the line remaining unaltered. We must now ascertain whether the total line intensities can change according to conditions. It can be shown that pressure has no effect upon the integrated intensities, while temperature has to a certain degree. According to quantum theory an emission or absorption of radiation corresponds to a transition between two distinct energy levels in a molecule. Let ϵ be the energy of a molecular level; then the relative concentration of molecules being in this particular state is according to Boltzmann's principle proportional to $e^{-\epsilon/kT}$. We are only interested in the relative change of the concentration with T. If the excitation energy ϵ is small, the Boltzmann function will be close to unity and a change in T has only a slight effect upon it. However, if the excitation ϵ is large, then the relative concentration $e^{-\epsilon/kT}$ of such states becomes small, but its variation with temperature becomes rather large. Returning now to the water molecule, a closer consideration of the structure shows that the spectral lines in the region between, say, 10 μ and 20 μ originate in higher excited states of the water molecule. Boltzmann's formula shows that a decrease in temperature results always in a decrease of the concentration of these states and thus in a decrease of the corresponding absorption coefficient. We cannot, however, determine this effect quantitatively, until this part of the spectrum has been analyzed. All we can say is that the absorption coefficient of water in the higher, colder parts of the atmosphere may in this spectral region be somewhat lower than the measured values. It seems difficult to decide at present how much of the difference in the absorption coefficients of steam and of moist air has to be attributed to this effect.

We consider now the CO_2 absorption band around 15μ. Rubens and Ladenburg (**17**) and especially Hertz (**18**) studied the variation of the absorption in this band in dependence upon pressure and partial pressure. Although the variation is measurable, it is comparatively small Thus, for instance, the same amount of CO_2 gives rise to an absorption of 86 percent in the middle of the band, if

under a pressure of 40 cm mercury and to 70 percent absorption under a pressure of 9 cm. This behavior is quite different from that of water vapor. It can be inferred from theoretical arguments that the individual lines which compose the absorption band of CO_2 must be rather close together. One can prove that if the cores of the lines do completely overlap, the absorption becomes independent of pressure. In the CO_2 band this condition is approximately realized. For computations of atmospheric transmission we may neglect the pressure dependence of the absorption in cases in which no great precision is required. There seem to be no other constituents of the atmosphere which absorb, appreciably, infrared radiation; ozone (19) in the concentrations in which it is present in the atmosphere is almost transparent in the far infrared.

CONCLUSIONS

In the preceding section we have tried to give an exhaustive enumeration of all the effects which under atmospheric conditions could possibly modify the absorption coefficient of water vapor. The main effect is the dependence upon pressure and temperature treated in the first section. There are two accessory features to be taken into account. The first is the appearance of gaps of partial or complete transparency in spectral regions which in Simpson's method are still treated as absorbing continuously; this refers especially to the region beyond 15μ. The gaps will appear at places intermediate between two lines; these effects can be calculated from the formulae given above, when somewhat more precise values of the line intensities are known. The second effect is the change of the total line intensities due to the change in concentration of the corresponding molecular states.

All the effects which have been mentioned in this paper tend to *decrease* the absorption coefficient as compared with the values used so far, especially in the higher levels of the atmosphere. Our results lend themselves to a number of applications concerning the absorption of terrestrial and solar radiation by the atmosphere which will be given at a later time. We might confine ourselves here to a few preliminary remarks. Simpson assumes in his work a content of about 0.3 mm of precipitable water for the whole of the stratosphere. Now under the reduced pressure this layer has an absorption corresponding to less than one-fifth of this amount of water under normal pressure. It follows that the stratosphere is practically transparent with the exception of the very narrow spectral regions occupied by the line cores. The flux of radiation through the stratosphere takes place principally in the cores; the radiation is therefore of a different spectral composition from that emitted by the troposphere. No direct inferences about the thermal state of the stratosphere can thus be drawn from a knowledge of the radiative transfer in the troposphere.

REFERENCES

(1) H. Rubens and G. Hettner, *Verhandl. deut. phys. Ges. 18*, 149 (1916); G. Hettner, *Ann. der. Physik, 55*, 476 (1918).
(2) F. E. Fowle, *Smithsonian Misc. Coll.* vol. 68, No. 8 (1917).
(3) L. R. Weber and H. M. Randall, *Phys. Rev. 40*, 835 (1932).
(4) G. C. Simpson, *Mem. Roy. Meteor. Soc.* vol. 3, No. 21 (1928).
(5) G. C. Simpson, *Mem. Roy. Meteor. Soc.* vol. 3, No. 23 (1929).
(6) C. G. Abbot, *Smithsonian Misc. Coll.* vol. 82, No. 3 (1929).
(5) H. Wexler, MONTHLY WEATHER REVIEW, *64*, 122 (1936).
(8) R. Mecke and others, *Zeits. f. Physik, 81*, 313, 445 and 465 (1933).
(9) See e. g., Leigh Page, *Introduction to Theoretical Physics*, Ch. XII.
(10) See e. g., A. Mitchell and M. Zemansky, *ResonanceRadiation and excited Atoms.*
(11) See V. Weisskopf, *Physikal. Zeits. 34*, 1 (1933).
(12) D. M. Dennison, *Phys. Rev. 31*, 503 (1928).
(13) See e. g., Geiger-Scheel's *Handbuch der Physik*, vol. IX, p. 399.
(14) E. K. Plyler and W. W. Sleator, *Phys. Rev. 37*, 1493 (1931).
(15) H. Kussmann, *Zeits. f. Phys. 48*, 831 (1928).
(16) H. Becker, *Zeits. f. Phys. 59*, 583 (1929).
(17) H. Rubens and F. Ladenburg, *Verhandl. deut. phys. Ges. 7*, 170 (1905).
(18) G. Hertz, *Verh. deut. phys. Ges. 13*, 617 (1911).
(19) G. Hettner, R. Pohlmann and H. J. Schuhmachez, *Zeits. f. Phys. 91*, 371 (1934).

ON PILOT BALLOONS AND SOURCES OF LIGHT FOR HIGH ALTITUDE UPPER-WIND OBSERVATIONS

By WILLIAM H. WENSTROM, Major, United States Army (retired)

[New Haven, Conn., October 1937]

The research described herein was begun in December 1934, in response to military meteorological problems, and continued as occasional opportunity offered until September 1937 when the work was necessarily terminated on account of administrative reasons. Due to these limitations, some of the data obtained are incomplete, and the results presented should be regarded as first approximations. They are nevertheless thought to be of general value to meteorologists, because the field has previously been little explored.

When cloudiness or poor visibility exists in the lower levels, upper wind determinations to high altitudes can be made only by means of the yet experimental radio pilot balloon,[1] or by means of expensive military techniques. The radio pilot-balloon problem is a complicated one, and its two-dimensional solution with a desirable precision of direction ($\frac{1}{10}$ of 1 degree) will probably require many years. The research described herein is concerned only with the far more simple problem of determining upper winds during the day or night to altitudes of 15,000 to 40,000 feet in good visibility under clear skies or high cirriform clouds. Recent aviation trends toward flying in the substratosphere, 20,000 to 30,000 feet, have brought this problem into immediate practical importance. In addition, high-altitude upper-wind observations are often useful to a weather analyst and forecaster.

[1] W. H. Wenstrom, Radiometeorography as Applied to Unmanned Balloons, MONTHLY WEATHER REVIEW, vol. 62, July 1934.

PILOT BALLOONS

Standard 6-inch pilot balloon.—The standard 6-inch pilot balloon, as used by the United States Weather Bureau and the Army Meteorological Service, weighs about 1 oz. (30 g) and costs about 10 cents. Inflated with hydrogen (cost about 10 cents) to a free lift of 4.66 oz. (137 g), corresponding to a sea-level diameter of about 2½ feet, it rises at an average rate (except in the zone of lower-level turbulence) of about 200 yards per minute. White, red, and black colors are available for use, respectively, under clear sky, cirriform clouds or darker clouds. A normally inflated balloon usually bursts at an altitude around 30,000 to 40,000 feet; but due to its small size, slow rise rate, increasing winds at upper levels, and the

optical limitations of standard theodolites, even under clear skies the balloon is usually lost to view (unless the upper winds are exceptionally light) at an altitude below 20,000 feet.

Balloon clusters and day beacons.—During the winter of 1934–35 at Bolling Field, D. C., and Aberdeen Proving Ground, Md., balloon clusters of various sorts were tried in an attempt to attain higher altitudes than were practicable with a single 6-inch balloon. A cluster of three or four white or red, or both, balloons, snugly tied neck to neck, was tried; also a tandem cluster of three balloons spaced about 20 feet apart along a string, the upper balloon being somewhat overinflated; results were slightly better than with a single balloon. Somewhat better results were obtained by hanging a "day beacon" (a large open cylinder of glazed white paper on a frame of No. 16 copperclad steel wire, size about 20 by 30 inches, weight about 2 oz., reflecting sunlight better than the balloons) about 50 feet below the cluster with a string. It is possible[2] to connect some device such as a water-filled copper tube (or perhaps a sealed glass vial) in the suspended string, so that the day beacon will drop when the freezing (0° C) level is reached. At night we used some four-candle lanterns (fully described below) with 6-inch balloon clusters.

All these early experiments served to show, however, that what we really needed was a larger pilot balloon. A 9-inch pilot balloon was used for high-altitude work by the Army Meteorological Service during the war, but was later discontinued. Large sounding balloons were available, of course, but were prohibitively expensive for ordinary upper wind observations.

Twelve-inch pilot balloon.—During the winter of 1934–35 Maj. A. H. Thiessen, Chief of the Army Meteorological Service at that time, set up specifications for a 12-inch pilot balloon, to be manufactured by a process of coagulation of latex on outside of spherical mold. Approximate characteristics:

Twelve-inch pilot balloon (day):
Balloon weight: 2¾ oz. (80 g).
Free lift: 15¼ oz. (430 g).
Average rise rate: 300 yd./min.
Average bursting altitude: 40,000 to 50,000 feet.
(Night):
Four-candle lantern weight: 5¼ oz. (150 g).
Free lift: 18 oz. (510 g).
Average rise rate: 220 yd./min.
Average bursting altitude: above 25,000 ft.
Also used with 7½ oz. 8-candle lantern, rising at 225 yd./min. when inflated to 22 oz.

During 1935 and 1936 about 250 ascents were made with this balloon at Bolling Field, Aberdeen Proving Ground, and at the temporary Stratocamp in South Dakota.[3] Best results were naturally obtained in the clear air of the West. The 12-inch balloon could be seen farther away than the 6-inch balloon, and its greater rise rate resulted in higher altitude for a given distance out. Double-theodolite day runs to 40,000 feet were easily made in light upper winds; heights greater than 20,000 feet could be reached even in high winds. At night the 12-inch balloon with a 4-candle lantern performed considerably better than the 6-inch balloon with a single-candle lantern; one run under favorable conditions was followed (by single theodolite) to an (assumed) altitude of about 27,000 feet above station or 31,500 feet above sea level. Large pilot balloons of this type, made by the latex-coagulation-on-outside-of-spherical-mold process though expensive (perhaps $2 per unit; hydrogen cost perhaps 30 cents per unit), are uniform in size, shape, and thickness. Their rise rates are correspondingly uniform, and suited to single-theodolite observations.

Sixteen-inch pilot balloon.—About 1936 a 16-inch (100 g) pilot balloon became available. The process consisted of spinning latex to general balloon shape inside a small spherical mold and expanding the hollow ball of latex thus formed, while still soft, to full 16-inch balloon size by air pressure. Compared with the older solid-spherical-mold process, this air-expanded process produces balloons that are considerably lighter and far cheaper (perhaps 50 cents per unit; hydrogen cost perhaps 50 cents per unit), but apparently less uniform. The balloons tested, at least, were not very uniform in size, shape or thickness; later models, it is understood, have been improved considerably in these respects. Practically, such inequalities result in an appreciable percentage of premature bursts; and (despite uniform inflation) in considerable and unpredictable variations of rise rate, necessitating double-theodolite observations. Far outweighing these disadvantages, however, is the high rise rate and lifting power of the 16-inch balloon.

During 1936 and 1937 we made about 200 test ascents at Bolling Field and Aberdeen Proving Ground with the 16-inch balloon, ascending both by itself and in combination with various weights and light sources. Preliminary tests showed that rise rates around 400 yd./min., attained with free lifts around 40 oz., were optimum; lower lifts and rates did not materially reduce premature bursts, while higher lifts and rates did increase them. As 400 yd./min. is a round number exactly twice the standard rise rate for 6-inch balloons, it was soon adopted as standard.

The highest free lift used was about 44 oz., which in winter gave rise rates around 400 yd./min. at the lower levels for the balloon alone. Above 10,000 feet this rise rate usually increased gradually, perhaps by 10 percent at altitudes around 30,000 feet, the increase being apparently due to some decrease in tumbling and oscillation as well as increase of the volume/area ratio. In summer the rise rate was higher, averaging 450 yd./min. in the lower levels for a free lift of 42 oz.; the upper level increase was less marked, perhaps due to steeper lapse rates in the summer atmosphere. Differences between the average rise rate of individual ascents amounted to 10 percent or so, occasionally to 20 percent. During an ascent, the rise rate was likely to vary from level to level by 10 to 20 percent. As a working free lift to approximate the 400 yd./min. rise rate through all levels under most conditions with the 16-inch balloon alone, 40 oz. appears to be the best figure. Summarizing approximate characteristics:

16-inch pilot balloon (day):
Balloon weight: 3½ oz. (100 g)
Free lift: 40 oz. (1,130 g)
Average rise rate (balloon only): Around 400 yd./min.
Average bursting altitude: 40,000 to 50,000 ft.

About 100 daytime ascents were made with the balloon alone under various conditions, at least 30 being checked by double theodolite to altitudes above 30,000 feet. Under clear skies and through average upper winds the white balloon could be followed with standard theodolites to distances of 20 or 30 miles and to altitudes of 40,000 to 50,000 feet. One observation in March extended to 36,000 feet altitude through winds of 90 m. p. h. at 10,000 ft., 70 m. p. h. at 20,000 ft., and 120 m. p. h. at 30,000

[2] J. F. Brennan—"A method of determining the altitude of the freezing point"—Mo. Wea. Rev., vol. 59, February 1931.

[3] W. H. Wenstrom—"Some Interesting Pilot Balloon Observations"—*Bull. Am. Met. Soc.*, vol. 16, Nos. 8–9, August-September 1935.

ft.; so it is probable that the 16-inch white balloon assures daytime, clear sky observations to 30,000 feet in any ordinary winds.

In 1937 some red 16-inch balloons were obtained, and tested against white balloons to altitudes around 30,000 feet. Under clear skies the white balloon gave a sharper image and could be followed to somewhat higher altitudes, though the red balloon proved nearly as good. Under cirriform clouds the red balloon was easier to follow, but with due care the white balloon could also be followed to high altitudes.

In connection with development work on the light sources described below, ascents were made with 16-inch balloons carrying various weights. The addition of any weight up to 5 or 10 oz., hung by a string 50 ft. below the balloon to minimize swinging, had much less effect on rise rate than one might expect; apparently the weight stopped tumbling tendencies and pulled the balloon into a more streamlined shape, thereby compensating for the loss of free lift. With a weight of 5 oz. or so, indeed, it seemed necessary, on the average, *to decrease* the free lift in order to obtain the same rise rate in lower and middle levels. With the weight, however, there was little if any increase of rise rate with altitude; at night, in fact, the rate usually decreased somewhat with altitude. In general, the rise rates with weights appeared to be more uniform at all times, and suggested the idea (which could not be thoroughly investigated) that dummy weights (say 5 oz. or so of some light, cheap material such as pasteboard) might profitably be used for better uniformity in daytime ascents. As an immediate and fortunate corollary of the balloon-plus-weight performance, it was evident that fairly heavy luminous sources could be carried up at 400 yd./min without overinflating the balloon.

SOURCES OF LIGHT

Six-inch balloon lights.—Standard lights for 6-inch balloons, as used by the United States Weather Bureau, are of two kinds: A single-candle lantern and a small electric light.

The single-candle lantern consists of a candle about ¾ inch (diameter) by 1 inch (long), candlepower about 1.0 and quite constant, burning time about 35 min.; mounted in the bottom of a cylindrical paper lantern about 4½ inches (diameter) by 8 inches (long), transmission of paper about 80 percent; weight complete about ½ oz. and cost perhaps 2 cents. Under average-visibility, clear-sky conditions, this lantern can be followed with a standard theodolite to distances of 3 to 6 miles, corresponding in various winds to altitudes of 6,000 to perhaps 15,000 feet above station at a rise rate of 200 yd./min.

The standard electric light consists of two 1.5-volt dry cells, size ½ inch by 1⅜ inches, and a flashlight bulb rated at 2.3 volts, 0.25 amps.; open circuit voltage 3.0; at start the closed circuit voltage is 2.3, the wattage 0.6, and the candlepower about 1; at assumed cut-off, after about 30 minutes, the voltage is 1.5, the wattage 0.3, and the candlepower about ¼; the light weighs about 1 oz. and costs perhaps 12 cents. Compared with the standard candle lantern, the electric light gives comparable altitude performance; it also eliminates fire hazard.

Four-candle lantern.—Any study of the problem of reaching higher altitudes with night upper wind observations at once suggests brighter light sources as the most obvious answer. The most promising immediate approach appeared to be an enlargement of the standard candle lantern. Experimentation with various sizes and arrangements of candles and lanterns, including some very large candles made to order, showed that the most practical development was a multiple arrangement of standard candles spaced about 2 inches apart in a completely closed paper lantern large enough so as not to catch fire. To reach distances and altitudes twice as great as those possible with the single candle lantern, at least four times as much light would be needed. The developed lantern had the following characteristics:

Four-candle lantern:
- Cylindrical white tissue paper lantern, 12 inches in diameter by 30 inches long; top and bottom frames, circular with cross pieces, of No. 16 copperclad steel wire soldered together at junctions; hanging wire to balloon string, and safety wire between top and bottom frames, No. 20 soft copper.
- Four-candle holder of ⅜-inch plywood, 3¾ inches square, having four 1 1/16-inch holes, drilled on diagonals, 1 7/16 inches from center so as to hold four standard ¾-inch candles, each 3 inches long, with wicks at the corners of a square 2 inches on a side; holder secured to bottom frame of lantern with thumbtacks.
- Weight complete: 5¼ oz. (150 g approximately).
  - Four candles: 2¾ oz. (80 g).
  - Candle holder: 1 oz. (30 g).
  - Lantern: 1½ oz. (40 g).
- Candlepower: About 4 to 6.
- Transmission through paper: About 70 to 80 percent.
- Burning time: About 50 minutes.

Four-candle lantern with 16-inch balloon:
- Free lift: 38½ oz. (1,090 g).
- Average rise rate: Around 400 yd./min.

While the lantern reaches 30,000 feet in 25 minutes and is usually lost earlier, the 50-minute burning time allows ample reserve for lighting the candles and pasting or clipping closed the bottom of the lantern at leisure, for use at a slower rise rate with a 12-inch balloon or underinflated 16-inch balloon, or for observations to extreme altitudes under very favorable conditions. The lantern is launched with even acceleration so that it will not jerk out of the hand. The launching location must be sheltered from anything greater than light surface winds, which might blow the side of the lantern into the flame. Once released, the lantern almost invariably stays lighted despite the terrific beating it takes from the combined forces of downdraft, humping, and swinging. One lantern, in fact, remained lighted for over a minute in free fall after its balloon burst at high altitude. As the candles burn down, a pool of wax forms on and around the candle holder; this finally ignites and burns away the lower part of the lantern; the air draft then extinguishes the flames entirely, so that, short of premature balloon bursts, the fire hazard is not serious.

Four-candle lanterns were used in about 60 test ascents, of which about 30 were night double-theodolite runs using 16-inch balloons. The large lantern presents a large lighted surface easily focused into a clear image. Several tests showed that it can be seen two or three times as far away as the single-candle lantern; and rising at 400 yd./min., it gives observations to altitudes two or three times as great as those possible with a single-candle lantern rising at 200 yd./min. Our best night observation with the four-candle lantern extended to 25,500 feet altitude above station, checked by double theodolite on the 20th minute when the lantern was about 13 miles distant and encountering 70-mile winds. A single-candle lantern released within the hour, under identical conditions, could be followed only to 8,000 feet altitude, where it was lost in 30-mile winds. On a winter night when winds above 10,000 feet were 60 to 90 m. p. h., four-candle lanterns were followed to 15,000 feet altitude, as against 7,000 feet for single-candle lanterns. All these tests, as well as the tests described hereafter, were made near the east coast where visibility is rarely very good; in the clear air of the

FIGURE 1.—Sixteen-inch pilot balloon inflated to 38½-oz. free lift, with 4-candle 5¼-oz. lantern, permitting night upper wind observations to altitudes of 15,000 to 30,000 feet.

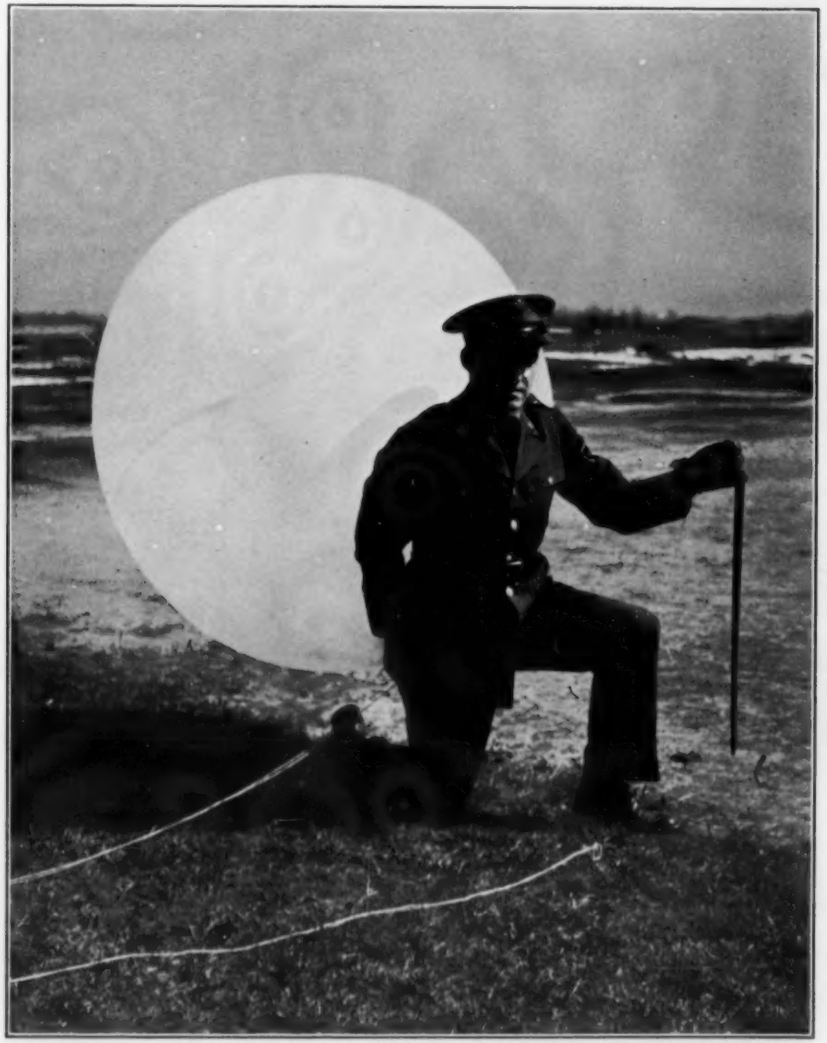


FIGURE 2.—Sixteen-inch pilot balloon inflated to 42-oz. free lift, with 7-oz. 40-minute experimental pyrotechnic flare.

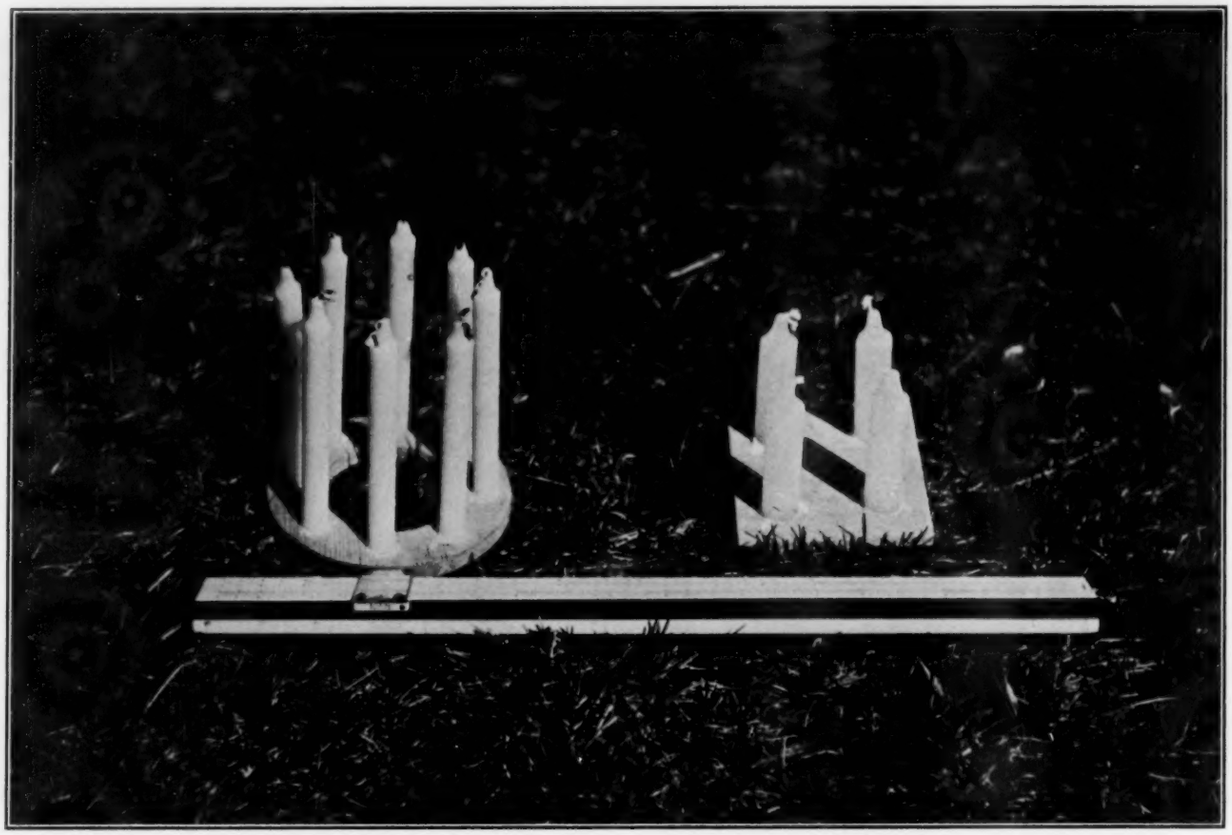


FIGURE 3.—Right: Four-candle unit as used in four-candle lantern. Left: An experimental eight-candle unit. Size comparison: 16-inch slide rule.

FIGURE 4.—Left: 3-watt 9-oz. electric light source giving night upper wind observations to altitudes of 15,000 to 25,000 feet. Right: Acetylene light source.

West, better results might be expected. Summarizing, we might say that the four-candle lantern can be followed by standard theodolites under favorable conditions to distances of 8 to 15 miles, corresponding in various winds to altitudes of 15,000 to 30,000 feet at a rise rate of 400 yd./min.

Six- and 8-candle lanterns.—In an effort to better the performance of the four-candle lantern and explore the limits of multiple-candle combinations, eight-candle and six-candle units were developed for use with the 12-inch by 30-inch paper lantern described above, which in itself represented a desirable limit of overall size.

The eight-candle holder consisted of a plywood ring drilled with eight ½-inch holes at 1½-inch intervals around a 4-inch circle, in which eight $^{17}/_{32}$-inch votive candles could be fixed. Candles 3½ inches long gave a lantern burning time of about 25 minutes and a total weight of about 5½ oz.; with 5-inch candles it burned about 35 minutes and weighed about 7½ oz. This lantern gave some increase of light over the four-candle type, but sacrificed too much in simplicity and reliability. It caught fire easily in light surface winds, and in some balloon tests went out at middle altitudes.

The six-candle lantern was developed to give somewhat more light than the four-candle lantern without sacrificing simplicity or reliability. To keep the weight within reasonable limits, however, it was necessary to sacrifice reserve burning time. Summarizing approximate characteristics:

Six-candle lantern:
- Cylindrical white tissue paper lantern, as described above.
- Six-candle holder of ⅜-inch plywood, 5½-inch ring with 2½-inch center hole, having six $^{17}/_{64}$-inch holes drilled at equal intervals around a 4-inch circle so as to hold six standard ¾-inch candles each 2 inches long with wicks spaced 2 inches apart around the circle.
- Weight complete: 6½ oz. (185 g).
  - 6 candles: 3 oz. (85 g).
  - Candle holder: 2 oz. (55 g).
- Candlepower: about 6 to 8 (less 20 to 30%).
- Burning time: about 25 minutes.

Six-candle lantern with 16-inch balloon:
- Free lift: 40 oz. (1,130 g).
- Average rise rate: Around 400 yd./min.

In addition to ground tests, only three double-theodolite night balloon ascents could be made with the six-candle lantern in the time available. In one comparative test under fair conditions the six-candle lantern was followed to 19,000 feet altitude as against 16,000 feet for the four-candle lantern. On another comparative test, both went to about 24,000 feet. By saving weight on the candle holder and lengthening the candles somewhat, the burning time of the six-candle lantern could perhaps be extended to 40 minutes, keeping the total weight under 7 oz. In its present form, the six-candle lantern appears to give slightly better performance than the four-candle lantern, particularly when visibility is only fair.

Another promising development that could not be completely tested was the four eight-candle lantern, which offered the very desirable quality of increasing candlepower. Characteristics:

Four eight-candle lantern:
- Paper lantern as described above.
- Candle holder: Same as in four-candle lantern.
- Four ⅜-inch candles, each 2½ inches long, are set in the four holes, same as in four-candle lantern. In addition, four ¼-inch candles, each 1¼ inches long, are set on the diagonals just inside of, and tangent to, the outer candles. Only outer candles are lighted at start; inner candles ignite from them after about 20 minutes.
- Weight complete: About 6¼ oz. (180 g).
- Candlepower: About 4 to 10.
- Burning time: Around 25 minutes. 400 yd./min. rise rate with 16-inch balloon given free lift of about 40 oz. (1,130 g).

No air tests could be made with this lantern in the available time. Ground tests (of candle unit in open air) showed candlepower about 4 at start, increasing to 5 and 6 within 15 to 20 minutes (due to mutual heating of four candles). At 20 minutes the first inner candle ignited; the second ignited at 21 minutes, raising the total candlepower to 8; the third lit at 23 minutes; the fourth lit at 25 minutes, raising the total candlepower to 9–10; at 28 minutes, two candles had burned down to the wood holder. Whether the inner candles would ignite properly in the lantern during a free asecnt, is not known; it is believed that some of them would, at least.

The large candle lanterns described above, compared with other possible light sources of comparable power, have several advantages: Universal availability of materials, low cost (about 6 cents), harmlessness on descent, and reliability. Of the three flame-type light sources that we tested, the candle lanterns alone remained lighted to altitudes above 20,000 feet. All the multiple-candle lanterns, also, have the desirable quality of increasing candlepower in some degree. The disadvantages of large candle lanterns are: Slight fire hazard, limited candlepower, handling difficulties unless carefully folded, and launching difficulties in high surface winds.

Three-watt electric light.—In order to obtain an electric light source about four times as powerful as the standard 6-inch balloon light, we tested various combinations of batteries and bulbs. For simplicity, only standard units in wide distribution were considered. It was early apparent that any electric light of this type would leave much to be desired in the direction of light weight and sustained candlepower. The best combination appeared to be as follows:

Three-watt electric light:
- Battery: Six 1.5-volt dry cells, size 1 inch by 1⅞ inches; six 8-volt auto bulb, rated at 3 watts or 1.5 candlepower; weight complete about 9 oz. (255 g); cost about 40 cents.
- Data at start: Open circuit voltage 9.0, closed circuit voltage 7.5, watts 3.4, candlepower about 4 to 5.
- Time at assumed cut-off 45 minutes; closed circuit voltage 4.5, watts 1.5, candlepower about two-thirds.
- Candlepower at 25 minutes (30,000 feet altitude): about 1.

Three-watt electric light with 16-inch balloon:
- Free lift: 42 oz. (1,190 g).
- Average rise rate: Around 400 yd./min.

In addition to ground tests, five double-theodolite night balloon ascents were made with this 3-watt electric light. Just before launching, the wire leads soldered to battery and bulb, scraped bright, were twisted together. During the first few minutes of any ascent, while the bulb operated at high efficiency above its normal voltage, the light was brilliant blue-white, and so steady that it showed in the theodolite considerably better than its measured candlepower would indicate. Later in the ascent, as the bulb efficiency declined, performance was about equal to, or slightly less than, that of the four-candle lantern. The best night altitude reached was 23,250 feet, when the light was about 10 miles away in 70-mile winds 18 minutes after leaving the ground.

The main disadvantages of the electric light are: Its considerable weight, considerable cost, and its very limited and steadily decreasing candlepower. Weight might be saved, and candlepower held nearly constant, by using specially built batteries of lead-acid type. The 9-oz. unit, falling from several miles altitude when the balloon bursts, would be a hazard to objects on the ground; for this reason a simple parachute, consisting of a cloth 3 feet square, was connected in the string between balloon and light. This parachute functioned satisfactorily when tested in the daytime under a balloon

carrying a small bursting charge of black powder attached to the neck, the powder being ignited after about 5 minutes of ascent by about 6 feet of blasting fuse. Also, as dry cells lose their efficiency very quickly at temperatures below about 5° F., some sort of heat-insulating material, such as several thicknesses of paper, has to be placed around the battery. The advantages of the electric light are: Ease of handling, ease of launching regardless of surface wind, steadiness and dependability of the light itself, and absence of fire hazard.

Acetylene light.—This light was developed by A. P. Rehbock. It consists of a 6-inch balloon inflated with acetylene, feeding a V-type burner protected by a conical, aluminum reflector-windscreen. The acetylene balloon hangs, burner downward, by a string from the main balloon; inflated to 12-inch diameter, the small balloon supplies the burner for about 35 minutes; the candlepower is around 20. The total weight is about 1 oz; cost, about 10 cents.

Acetylene lights were tested in five night-balloon ascents, two at a 200 yd./min. rise rate (16-inch balloon; free light 10 oz.), and three at a 400 yd./min. rise rate (16-inch balloon; free lift 38 oz.). At 200 yd./min. the light performed well—certainly much better than a single-candle lantern or small electric light of comparative weight. But the acetylene light flickered badly (at a period of about one-half second), at times disappearing altogether for a moment. Each fade and come-back was so rapid, however, that the light could be easily followed with a theodolite.

At 400 yd./min. the acetylene light went out in all three tests, one at a few hundred feet, one at 7,000 feet, and one at 14,000 feet. From these incomplete data, it would appear that the present form of acetylene light is not reliable at the high rise rates which are necessary to reach high altitudes in high winds. Perhaps changes in design, such as an improved reflector-windscreen, would remove this defect. The acetylene light's advantages are light weight, low cost, considerable candlepower; its disadvantages are difficulty of handling, inflation, etc., flickering, and (at present) unreliability.

Pyrotechnic flare.—At the Stratocamp in June 1935, while experimenting with 12-inch balloons and four-candle lanterns, we made several night balloon tests with small, standard railway flares. The ¾-inch, 10-minute flare weighs about 5 oz., and burns with a brilliant red light of more than 200 candlepower; our night balloon tests showed it to be far superior to any other light source during its short burning time. In spite of some fading, the light was so powerful that it could be easily picked up with the naked eye at a distance of 3 to 5 miles. The problem was to develop a red flare that weighs less than 10 oz., and burns at least 30 minutes under a balloon rising at 400 yd./min., with candlepower at least 50 at the start and preferably increasing gradually to several hundred as the balloon rises. The problem is still unsolved, despite considerable work by experts in the fireworks field, but considerable progress has been made.

Other pyrotechnic lights, such as magnesium ribbon, magnesium flares, and sparkler material were considered, experimented with, and dropped in favor of the more promising red flare; red light penetrates haze best, and is easily distinguished from stars. Over a period of more than a year, samples of four flare models were submitted, each in some respects an improvement on the preceding one.

The first flare model embodied a flare tube around 50 inches long; its small (initial) end diameter was about 1/16 inch (the smallest diameter that would burn evenly and reliably in still air), increasing constantly to about ½-inch diameter at the large (terminal) end; the weight was about 7 oz. The flare tubing was arranged in spiral form on a light metal frame, to burn inwards from the small end to the large end in about 40 minutes, with candlepower increasing gradually from about 20 to about 100. Tested on the ground, this flare burned satisfactorily except for severe dimming (perhaps due to conductive loss of heat) where the burning end of the tube passed the metal frame members. In about six night balloon tests this dimming was very apparent, though the light usually brightened again before it was lost to the theodolite. The best ascent reached an altitude of about 14,000 feet. In some ways this flare, with its tube hung horizontally, perpendicular to the slipstream, performed better than later models that were hung vertically. Some of our later flares performed satisfactorily under fan downdrafts up to 20 m p. h., yet went out in air tests. The wriggling, swinging, humping motion of the balloon rising at 400 yd./min. was something, apparently, that could not be duplicated by any tests on the ground

The second flare model, to obviate the dimming noted above and to simplify construction, was a straight, tapered tube. It was 25 inches long; the diameter was three-sixteenths inch at the lower (initial) end and thirteen-sixteenths inch at the upper end, whence a wire connected to the balloon string; the weight was 7 oz. and the burning time (horizontal in still air) 45 minutes; the candlepower increased gradually from about 30 at the start to around 150 at the end. About six night balloon tests showed that some fading had been eliminated, but considerable remained. All these flares blew out at altitudes below 10,000 feet, probably because the composition was too slow-burning and the initial diameter too small. Although the idea of a tapered tube and increasing candlepower was abandoned in succeeding models in order to simplify construction and reduce cost, it is believed to be worth further consideration.

The third and fourth flare models were straight, uniform cylindrical tubes, similar to railway flares but thinner and longer. Summarizing their characteristics:

No. 4 pyrotechnic balloon flare:
- Size: 1 1/16 inch (diameter) by 24 inches (length).
- Weight: 9½ oz. (270 g).
- Burning time: About 30 minutes.
- Candlepower: Average about 100.
- Candlepower for last minute: More than 500.

Flare with 16-inch balloon:
- Free lift: 42 oz. (1,190 g).
- Average rise rate: Around 400 yd./min., variable.
- 16-inch safety balloon inflated to 10 oz.

Tests with the model 3 flares showed considerable fading, apparently caused by temporary accumulations of ash from the pasteboard container tube as it burned away. These ash cones would stifle the flame somewhat for several seconds, then drop away. Consequently a faster-burning composition was used in model No. 4 (necessarily cutting down the burning time), with improved results.

Fourteen night-balloon tests were made with model 4 flares. They showed some fading, inseparable from any light source of this type; but the fading was not serious, and at lower levels the light was far brighter and clearer than any other balloon light, being visible for several minutes to the naked eye as a red, overbright star. The best altitude checked by double theodolite was 17,280 feet, when the light was about 6 miles distant in 17-mile winds. It disappeared suddenly from satisfactory brilliance. Ten of the flares went out similarly at altitudes between 9,000 and 16,000 feet. It is possible that lack of oxygen, which would be apparent at these altitudes,

was the cause; though the composition includes its own oxygen, atmospheric oxygen might be necessary to the steady burning away of the pasteboard.

From the results described above, it appears that a still better flare might be built on the following specifications, using a fairly quick-burning composition: Tube, of diameter increasing from about eleven-sixteenths inch at lower (initial) end to about seven-eighths inch at upper end; candlepower gradually increasing from about 100 at start to about 500 at end; burning time, 25 minutes; weight, less than 12 oz. This desirable development, however, could not be undertaken in the time available.

The disadvantages of the flare are its unreliability (at present), its fairly heavy weight, and its serious fire hazard. In one or two of our tests, flares dropped several thousand feet due to wire breakage or premature balloon burst, and remained lighted all the way to the ground. We therefore used a strong (No. 16 copperclad steel) safety wire, and also a safety balloon on each of the later ascents. The function of the safety balloon, a 16-inch balloon inflated to 10 oz. free lift, was to hold the flare off the ground in case the lifting balloon burst; for least oscillation and most uniform ascent rate, the two balloons are preferably tied neck to neck. The advantages of the flare are its simplicity, ease of launching, and its outstandingly bright light when operating properly.

OBSERVATIONAL TECHNIQUE

Theodolite considerations.—All the tests described above were made with the standard theodolites in common use for upper wind observations. The observation of a planet or two (such as Jupiter and Saturn) with this instrument reveals that, optically, it leaves much to be desired. For high altitude night observations a larger objective—say 60 mm—would be far more satisfactory due to its increased light-gathering power and better definition. Two or three eyepieces, quickly interchangeable, say 10X, 20X, and 40X, should be provided. In daytime observations under a clear sky, a red filter can often be used to advantage, the balloon appearing as a bright red speck against a dark background. When trying for extreme altitude under unfavorable conditions (far out, the balloon appears as a very faint and evanescent speck), each theodolite should be manned by two men—one to follow the balloon and the other to read the scales.

For night work the reticule should be lighted internally and the scales lighted externally; the brightness of each electric bulb being controlled by a separate rheostat. Above 10,000 feet, under most conditions, two men should be on each theodolite. The theodolite must be screened from nearby surface lights that bother the observers.

Single versus double theodolite.—The average rise rates of 6-inch balloons have been thoroughly studied.[4] [5] Formulas have been developed giving rise rate in terms of balloon weight and free or total lift; with the small balloons these formulas are reasonably accurate. With the standard free lift, 4.66 oz. (137 g), a 6-inch balloon usually (but not always) ascends at a rate within ± 10 percent of 200 yd./min. Most of any series of ascents will be within the ± 10 percent limits, but occasionally a balloon will depart widely from the standard rate, perhaps by as much as 50 percent. It is apparent, therefore, that a one single-theodolite balloon ascent cannot be trusted blindly for accuracy (if accuracy in a given case is important), although in general the upper winds are given by single theodolite accurately enough for present-day uses. There is in aviation, however, some demand for more dependable upper winds expressed in magnetic degrees of azimuth.

Our tests with the 12-inch balloon showed that, in general, with a single theodolite, it would give results about as good as the 6-inch balloon. For dependable upper wind observations to high altitudes with the 16-inch balloon (and no smaller balloon dependably reaches these altitudes), our tests showed double-theodolite observations to be very desirable.

Double-theodolite observations mean, in optimum practice, three theodolite positions located to form two alternate base lines roughly at right angles. For best results all three theodolites should be manned, the base line being changed as necessitated by the balloon drift. Even for high-altitude observations, 2-mile base lines usually suffice. All theodolite stations should preferably be connected to the plotting board by dependable wire telephone.

With a well designed plotting board, double or triple theodolite determination of upper winds is simple and easy. The board used in most of our tests was developed as the result of several years' experience at Aberdeen Proving Ground. The fixed center pin represents the balloon. From this pin radiate three arms (set with reference to a large degree circle on the board) representing azimuth from station A, azimuth from station B, and elevation from station A. The station A azimuth arm is provided with a perpendicular altitude arm (set against the station A elevation arm). Any desired base line can be chosen from a four-theodolite network; on the board a base line (or double or quadruple base line) is represented by a small ruler-like straight edge clamped to a drafting machine which holds it always parallel to its actual azimuth wherever it is moved on the board. Base lines can be switched during an ascent, and velocities of upper winds are determined as the balloon rises to new levels without any delay.

High-altitude upper-wind possibilities.—Regardless of aviation or other demand, it would not seem possible to put in high-altitude facilities at each of the eighty-odd upper-wind stations now operated by Weather Bureau, military and naval, and private services in the United States. One might visualize, rather, a limited network of 15 or 20 high-altitude, upper-wind stations superposed on the denser low-altitude network. The high-altitude upper, wind stations, indeed, might coincide with the present airplane-sounding stations, which should change gradually to radio-sounding-balloon stations in any case. Eventually, when better solutions are found to the difficult radio-pilot-balloon problem, the same stations could be used for this purpose also. Thus 15 or 20 high-altitude upper-air stations scattered over the United States might eventually determine upper winds to 30,000 feet altitude by balloons and light sources similar to those described above, under clear skies or cirriform clouds; they might determine upper winds by radio-pilot balloon through lower clouds or poor visibility; and they might determine air-mass characteristics from pressure, temperature, and humidity values given by radio-sounding balloons.

ACKNOWLEDGMENTS

The writer acknowledges with gratitude the assistance of the following noncommissioned officers of the Army Meteorological Service in this research: H. J. Pryber, R. M. Glenn, L. B. Burke, W. F. Bernheisel, F. A. Matchinski. Also gratefully acknowledged is the cooperation of Lloyd A. Stevens of the United States Weather Bureau, and Capt. D. W. Watkins and Lieut. F. B. Wood, Air Corps, United States Army.

[4] B. J. Sherry. The Rate of Ascent of Pilot Balloons. M. W. R. vol. 48, December 1920.

[5] W. C. Haines. Ascensional Rate of Pilot Balloons. M. W. R. vol. 51, May 1924.

TROPICAL DISTURBANCES ON THE NORTH ATLANTIC OCEAN AND GULF OF MEXICO, SEPTEMBER 1937

By WILLIS E. HURD

[Weather Bureau, November 1937]

Five disturbances of tropical origin were charted in North Atlantic waters (including the Gulf of Mexico) during September 1937. A sixth disturbance may be mentioned in connection with those of September, as it originated on the 30th. Two of the six were confined almost entirely to the Gulf of Mexico, and were of only minor intensity. Of the remaining four, one, of moderate energy, passed up the east coast of the United States and entered the open ocean beyond Newfoundland; the other three, two of which developed known hurricane intensity, originated to the eastward of the Leeward Islands and moved generally to the northward. Two of them entered the continent at Nova Scotia, while one, with a northeasterly inclination, entered high latitudes wholly away from land.

The tracks of all these disturbances are shown in the accompanying figure, numbered I to VI, chronologically.

Disturbance of September 9–14, 1937.—(Track I.) As early as September 6 disturbed conditions existed in the vicinity of 14° N., 44° W., but it was not until the 9th that a more positive development was reported. At 4 a. m. of that date a radio message was received from the French motorship *Fort Royal*, in latitude 18°40′ N., longitude 55°06′ W., reported a barometer of 29.71, falling rapidly, with gusty east winds, heavy rain, and very heavy seas. Four hours later, with the ship near 19° N., 55° W., the wind had changed to south, force 7, while the barometer had fallen to 29.65. At regular p. m. observation of the 9th a southeast gale of force 9, barometer 29.80, was reported by another ship in 20°12′ N., 53°54′ W.

At 10 a. m. of the 10th, in latitude 21°30′ N., longitude 57°12′ W., the British steamer *Winamac* had a barometer reading of 29.39 inches, with a north-northeast gale of

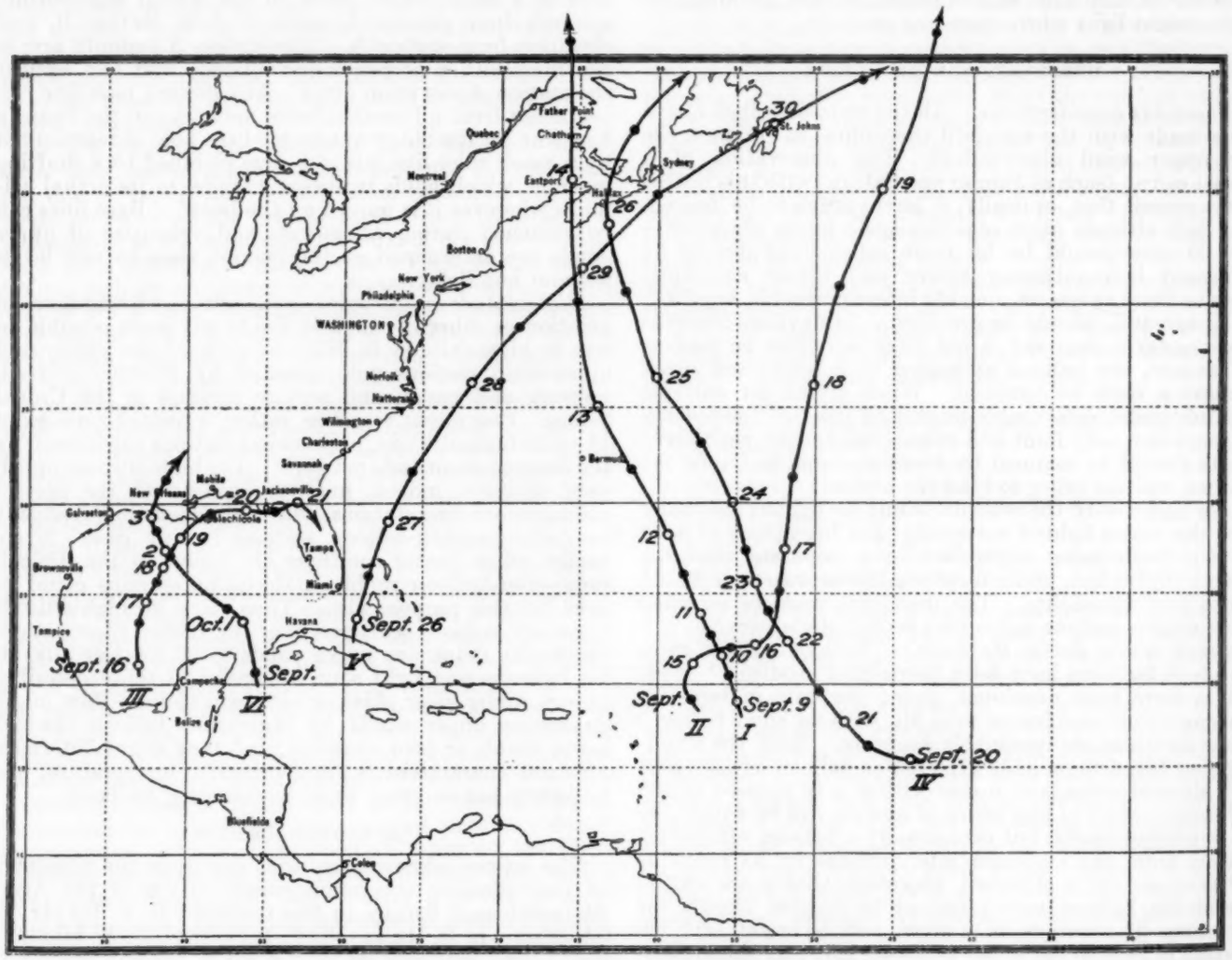


FIGURE 1.—Approximate tracks of tropical disturbances, September 1937.

force 10. At local noon the wind had changed to south-southwest, force 9, with rising barometer. At 6 p. m., of the 10th the Dutch steamer *Telamon*. in 24°21′ N., 57°16′ W., had an east-southeast gale of force 8, barometer 29.68.

On the morning of the 11th the storm center was approximately at 24° N., 57½° W., moving north-northwestward. Ship reports were few, but an 8 a. m., local time, observation from the German steamer *Vegesack* gave a northeast wind of force 9, barometer 29.77, near 25° N., 60° W.

During the remainder of the 11th and through the 12th, on the night of which the storm passed east of Bermuda, little is known of the storm's intensity beyond that indicated by a few ships which reported moderate to fresh gales well outside the center. At 2:30 a. m. of the 13th, however, the British steamer *Cadillac*, in 33° 50′ N., 63° 20′ W., had a north gale of force 9 and a barometer of 29.30 inches, which indicated the center to be a short distance to the eastward, and still moving in a north-northwesterly direction.

During the night of the 13–14th the storm, then progressing almost due northward, showed little change in depth, with the British steamer *Cyrus Field*, in 42° 50′ N., 65° 48′ W., at 5 a. m., reporting a barometer of 29.30 inches, wind north-northwest, force 7. About 2 hours earlier this ship, northbound, had highest wind force, 9, from the northeast. The strongest gale reported on the 14th was at 1 a. m., when the British steamer *Darcoila* had a wind of force 10 from the south-southwest, barometer 29.30, in 43° 20′ N., 64° 50′ W. At 8 a. m. of the 14th the center, after crossing western Nova Scotia, passed near Eastport, Maine, where the barometer read 29.48 inches. Thereafter the disturbance moved rapidly northward across New Brunswick and at 8 p. m. of the 14th lay over the lower St. Lawrence Valley.

The most dramatic incident in connection with this entire disturbance was the disappearance of the British racing yacht *Endeavor I*, after breaking loose from tow in the storm on the 13th, when about 200 miles east of the Nantucket Lightship, with 18 persons on board. Several days' search for the missing vessel failed to disclose her whereabouts until the 22d, when she was sighted about 260 miles from Fastnet Rock.

Advisory messages regarding this disturbance were first issued from the Forecast Center at San Juan, P. R., on the 9th and continued until the 10th. Thereafter, continuing through the 12th, advisories were issued by the forecaster on duty at Jacksonville. At 10 p. m. of the 13th the Washington forecaster ordered northeast storm warnings on the New England coast from Boston to Eastport. These were hauled down on the 14th after the passage of the storm inland.

Hurricane of September 14–19, 1937.—(Track II). A tropical storm of near-hurricane intensity when earliest reported appeared near midday of the 14th near 20° N., 57° W. At 1 p. m., local time, of that date, the Norwegian motorship *California Express* experienced a southeast gale of force 11, barometer 29.57, in 20°12′ N., 57°18′ W. At 7 p. m., E. S. T., the ship had a northeast gale of force 9, barometer 28.72, near 20° N., 58° W. At 1 a. m. of the 15th, in 20° 39′ N., 57°48′ W., she reported a barometer down to 28.20 inches, with an east-northeast gale of force 9. At 7 a. m., E. S. T., near 21½° N., 57½° W., the wind at ship had changed to northeast, force 7, barometer 28.29. At the same time the British S. S. *Glendene*, near 22° N., 58° W., had a northeasterly wind of force 8, barometer 29.68. The storm appeared to be moving slowly during the 17th, at first in a northerly, then in a northeasterly to east-northeasterly direction.

At the morning observation of the 16th no very low barometer was in evidence, but near-hurricane winds continued, with the British motorship *Atheprince* reporting a northeast gale of force 11, barometer 29.41, near 22½° N., 54° W. During the afternoon of the 16th the storm took a north-northeast course. There were then few reporting ships in the immediate vicinity of the center, one of the nearest being the Dutch steamer *Crynssen* which, near 22° N., 51° W., had a southwest wind of force 7, barometer 29.89. Early in the morning of the 17th, according to a report received at Bermuda, the Norwegian motorship *Teddy* passed very close to the center, in about 26°50′ N., 51° 40′ W., with barometer 28.60 and winds of force 11 to 12 shifting from southeast to northeast and northwest, with heavy rain and seas. Later, at morning observation of the 17th, the French S. S. *Carimare*, near 27½° N., 52½° W., had a north wind of force 9, barometer 29.50, and close by to the eastward a ship (name not reported) had a gale of like force from the northeast, barometer 29.09. The storm at that time was centered close by and moving more rapidly northward.

During the 18th the cyclone appeared to have gathered energy. At about 3 a. m., local time, the American steamer *Otho*, near 34° N., 50° W., encountered a southeasterly hurricane, changing at 5 a. m. to a north-northwest hurricane, lowest pressure 28.54. At 11:30 a. m., near 35° N., 48° W., the British steamer *Oropesa* had a hurricane wind from southeast, barometer 29.53. Early in the afternoon of the 18th the Italian motorship *Maria*, near 37½° N., 45½° W., met a south gale of force 9, barometer 29.92 and at 4 p. m., near 36½° N., 46½° W., the Belgian motorship *Lubrafol* had a like gale, barometer 29.80.

By night of the 18th the hurricane, then moving on a north-northeast course, was centered near 40° N., 49° W.

The intensity of the storm on the 19th is well shown by excellent special reports furnished by the American steamer *City of Newport News*, Capt. Robert L. Wright, to the United States Hydrographic Office, and the Dutch steamer *Bilderdyk*, Capt. C. H. P. Coster, to the United States Weather Bureau. The S. S. *City of Newport News*, bound from Havre toward Norfolk, after encountering severe gales on the eastern side of the hurricane during the morning, ran into the calm center at 46° 20′ N., 46° W., at 9:20 a. m., barometer 28.65. "We were treated," said Captain Wright, "to a perfect exhibition of the old story—'the eye of the storm'—the wind dropped from force 11 to a dead calm, the sea suddenly lost its strength, and long and confused swells continued running from the south-southwest. At that time the sun came out blindingly—a sickly yellow—and occasional patches of blue sky appeared momentarily around its vicinity. This condition lasted for 18 minutes." The ship's lowest barometer, 28.55, was read at about 9:37 a. m., local time, when the wind shifted to northwest. The highest wind on the ship was from the northwest, force 12.

The Holland-America Line steamer *Bilderdyk* was en route from Rotterdam to New York; her noon position on the 19th was at 47°29′ N., 40°06′ W. At 3 p. m., according to Captain Coster's report, the ship had run into the storm, with a southeasterly wind of force 9. The gale increased to a south-southeast hurricane at 5 p. m. and so continued until 6:30 p. m., when it lightened to force 6, near the storm center, and changed to south-southwest, thereafter increasing to force 11 from the southwest. The lowest barometer on ship was 28.93, with the instrument fluctuating by about a millimeter between 6 and 6:30 p. m., local time.

Thereafter, the storm passed rapidly into high northern latitudes and on the 22d was central near Iceland.

During the early stages of this disturbance in low latitudes, advisory messages were issued concerning its movements from the Forecast Centers at San Juan and Jacksonville.

Disturbance of September 16–21.—(Track III.) Somewhat disturbed weather conditions occurred over the southwestern part of the Gulf of Mexico on September 16, with slight lowering of pressure and evidence of a cyclonic circulation. The center of the depression was near 21° N., 93° W., in the morning and about 3° farther north 12 hours later. The highest wind reported in connection with it during the day was from the northwest, force 5, near 23° N., 94½° W., at 1 p. m., local time.

The disturbance moved slowly in a north-northeasterly direction with little general change in energy during the 17th and at 6 p. m., E. S. T., was central at approximately 25½° N., 92° W., but the weather was unsettled over much of the northwestern Gulf. At 10 a. m., according to a belated report, the American steamer *Oliver Olson* met a local gale of force 10 from the northeast, barometer 29.74, in 26°55′ N., 91°37′ W. This was the only high wind reported from the vicinity of the disturbance during the day.

On the 18th and 19th the region was more generally disturbed and several ships in the northern Gulf reported winds of force 7 on both dates. The highest reported at sea in the 2 days was of force 8, from the southeast, barometer 29.72, experienced by an unidentified vessel near 28° N., 89° W., at 7 p.m. of the 18th. At 3:30 p. m. of the 19th the center turned more to the east and passed over Port Eads, with barometer reading of 29.64, the lowest recorded during the existence of the depression. Quoting from the report of R. A. Dyke, forecaster in charge at New Orleans:

> The wind at Port Eads on the 19th veered from south at 7:30 a. m. through west at 1:30 p. m. to north at 4 p. m. An incomplete wind velocity record at Port Eads gives a 5-minute maximum of 34 miles per hour at 3:28 p. m. and an extreme velocity of 41 at 3:32 p. m., both on the 18th.
>
> Winds at Pensacola were highest on the 19th, with maximum of 28 miles per hour from the south. Winds at Apalachicola on the 20th were from south and southeast to 10 a. m. and veered through south and southwest to north at 3 p. m. The lowest pressure was 29.79 at 2:30 p. m. on the 20th and the highest wind was 30 miles per hour from the south at 5:28 a. m. on the 20th.

The depression moved in a general easterly direction across the extreme upper part of the eastern Gulf during the late 19th and the 20th, and disintegrated over northern Florida on the 21st. The average rate of movement along the entire track was about 9 miles an hour. No damage of importance resulted from the disturbance, although some injury was done to highways from the heavy rains south of Tallahassee.

During the 17th to 20th storm advisories and warnings were issued from the Weather Bureau office at New Orleans at frequent intervals.

Hurricane of September 20–26, 1937.—(Track IV.) Radio reports from ships in low latitudes early on the 20th showed the existence of an already well-developed storm of considerable extent with center in approximately 15° N., 44° W. At 9 a. m. the British steamer *City of Batavia* reported a southeast gale of force 10, barometer 29.60, in 18°06′ N., 44°15′ W., and at 10 a. m. the British motorship *Caprella* reported a southwest gale of force 11, barometer 29.48, in 14° N., 43° W.

On the 21st no ships appeared to be in the near neighborhood of the center of the disturbance, but at about 9 a. m., local time, an unknown vessel near 23° N., 49° W., reported a southeast wind of force 7, barometer 29.82. Twelve hours later the American steamer *Cliffwood*, in the same position, had a similar wind, barometer 29.86.

On the morning of the 22d reports from the French steamer *Marigot* and another vessel, unknown, located the center with closer definiteness, and showed that the storm was moving in a northwesterly direction. The *Marigot* had a west gale, force 8, barometer 29.65, near 21½° N., 54° W., and the other ship, a northwest wind of force 9, barometer 29.29, near 22½° N., 52½° W. In a special mail report later received from the *Marigot*, a northwest wind of force 10 was noted as experienced at about 2 a. m., local time, barometer 29.19 (uncorrected), near 22½° N., 52⅔° W. At regular p. m. observation of the 22d the wind reported by a ship in the storm area was of force 10, from the northeast, barometer 29.53, near 25° N., 54° W.

During the 23d the storm continued to move slowly northwestward, accompanied by strong to whole gales, lowest reported barometer 29.12, within the region 26°–28° N., 52°–56° W.

On the 24th the disturbance moved with greater rapidity. The center at 7 a. m., E. S. T., was near 30° N., 55° W., accompanied by heavy rains and local gales, a northwest wind of hurricane force being reported by the German Steamer *Nordenham*, barometer, 29.44, near 29½° N., 57° W. At 9 a. m., local time, an unidentified ship in 31°36′ N., 54°48′ W., had an east gale of force 10, barometer 29.29. During the day the storm center passed at a distance of several hundred miles to the eastward of Bermuda, and on the morning of the 25th was northeast of the island, centered near 36½° N., 60° W. At evening observation of the 25th the center had moved to about 40½° N., 62½° W., with lowest pressure 28.94 inches, and strong winds to gales of force 10 blowing over the surrounding sea.

In crossing Nova Scotia during the 26th, the storm recurved into a northeasterly direction, crossed northern Newfoundland near the Strait of Belleisle during the night of the 26–27th, and by the 30th was over Iceland.

Ample advisories and warnings of this disturbance were issued, first, on the 20th, from San Juan, P. R.; then from Jacksonville, Fla., on the 22d to 24th; and from Washington, D. C., on the 25th and 26th. At 10:10 a. m., E. S. T., of the 25th, northeast storm warnings were ordered along the New England coast from Block Island to Eastport, and whole gale warnings along the east Maine coast at 6:50 p. m. These were continued until 9:30 a. m. of the 26th, at which time the storm was over Nova Scotia with a north-northeasterly trend in direction.

Disturbance of September 26–30, 1937.—(Track V.) Slight evidences of a cyclonic circulation appeared between the central north coast of Cuba and the Bahamas on the morning of September 26. The disturbed condition moved north-northeastward as a very shallow depression, accompanied by light winds, and at 7 p. m., E. S. T., of the 27th was central near 31½° N., 75½° W. Its course thereafter curved more into northeasterly.

On the morning of the 28th the center lay at some distance east of the Virginia Capes, continuing shallow and poorly developed. At this time, however, with high pressure on the west, north, and east, the wind circulation became more energetic and winds of force 7 occurred on its west and north quadrants. At 4 a. m. of the 28th the American steamer *Gulfhawk*, in 34°40′ N., 75°27′ W., had a north-northeast wind of force 7, barometer 29.83 inches. Later in the day this ship experienced a northeast gale of force 8, the highest wind velocity reported by a ship in connection with the disturbance as it moved up the coast.

Thereafter, the center of the deprsesion continued at some distance from the coast until the 29th when it

skirted Nova Scotia close to the southward. On the morning of the 30th it crossed southeastern Newfoundland and late in the day merged with an extratropical cyclone in the high latitudes of the North Atlantic.

Relative to this disturbance, an advisory warning was issued by the Forecast Center at Jacksonville at 10 a. m. of the 27th, and storm warnings were ordered hoisted on the 28th from the Virginia Capes to Eastport, Maine. The latter order was issued by the Washington Forecast Center.

Disturbance of September 30–October 3, 1937.—(Track VI.) Slightly threatening conditions appeared over the southern part of the Gulf of Mexico and the western Caribbean Sea on the afternoon of September 30, with some evidences of cyclonic circulation centered a little south of the Yucatan Channel.

At 6 a. m., local time, of October 1 the center of the condition appeared to be at approximately 23½° N., 86° W. No wind exceeding force 6 occurred there during the day. The center moved very slowly northwestward between 6 a. m. and 6 p. m., but with much greater rapidity from then until the morning of October 2, when it lay near 27½° N., 91° W. The Honduran steamer *Morazan* reported a barometer of 29.62, wind southeast force 3, near this position. This pressure reading is the lowest of record in connection with the disturbance.

The center of the LOW continued to move toward the northwestward until the night of the 2d, when it turned toward the north and entered the Louisiana coast at Atchafalaya Bay at about noon of the 3d.

Only one report of a gale wind connected with the disturbance in mid-Gulf is now at hand. This was experienced by the American steamer *Gulfprince*, from east-southeast, force 8, barometer 29.93, in 26°36′ N., 88°12′ W. at 7 a. m., local time, of October 2, at a considerable distance to the eastward of the center at that time. It may be mentioned, however, that at about 9 p. m. of September 30 the American steamer *Seminole* reported a northeast gale of force 8 in the vicinity of 27° N., 88° W., at that time far to the northward of the center of the unsettled area. On October 1, it may be mentioned further, a second LOW of some energy showed signs of developing in the Yucatan Channel, and at about noon, local time, the Honduran schooner *Racer* reported a gale of force 10 off the western end of Cuba. This secondary LOW deteriorated rapidly, however, and later merged with the primary LOW to the northward.

From late on September 30, until the principal LOW went inland in Louisiana on October 3, frequent advisory messages were issued by the forecaster at New Orleans. On October 1 storm warnings were ordered along the coast from Panama City, Fla., to Morgan City, La., and were extended at night as far eastward as Carrabelle, Fla., and on the 2d from Carrabelle to Port O'Connor, Tex. All warnings were lowered on the 3d.

NOTES AND REVIEWS

Note on H. C. Huang's Investigations of Frontogenesis in the North Pacific. By PAT J. HARNEY. Two years ago R. W. Richardson presented the results of his study of storm tracks and their relation to the frontal zones and to the distribution of air masses over the North Pacific Ocean before the Association of Pacific Coast Geographers at Los Angeles. His curves of "cyclone frequency" were subsequently published in the MONTHLY WEATHER REVIEW in his article "Winter Air Mass Convergence in the North Pacific." [1]

These curves have recently been used in checking the calculated position of the Polar Front over the North Pacific by H. C. Huang of the National Central University of Nanking, China. While a graduate student of the California Institute of Technology, Huang determined the regions of frontogenesis over the North Pacific in the manner developed by Petterssen; [2] the results form part of a thesis at the California Institute and will subsequently be published by the National Research Institute of Meteorology at Nanking, China. The object of this note is to call attention to the results of these two studies of weather over the North Pacific, which give a useful check on the theoretical methods advanced by Petterssen.

For answering some of the questions on the location of the Polar Front in the Far East two of the charts for the winter season from his paper, Frontogenesis in the Far East, are here reproduced.

A brief comment on the method may be appropriate. Starting from the concept that frontogenesis will occur where the motion is such as to increase the concentration of iso-alpha lines (here representing temperature) until a marked discontinuity exists, the formula correlating the motion of the air and the properties of the iso-alpha field, as developed by Petterssen, may be written,

$$F=a(\cos 2\psi-\cos 2\psi')|\nabla\alpha|$$

where F, the frontogenetical function, is a product of a, the dilatation term of the field of motion (in which ψ is the angle a tangent to the isotherms makes with the dilatation axis or deformation axis of outflow and ψ' is the angle the line $F=0$ makes with the dilatation axis) and $|\nabla\alpha|$, the magnitude of the ascendant of the property α.

To evaluate the function F over the North Pacific, Huang combined the streamlines constructed by W. Werenskiold,[3] for this season with the surface-wind data available from his country, and located the hyperbolic streamline patterns which indicated the existence of the deformation fields shown on figure 1. The superposed isothermal field gave values of $|\nabla\alpha|$, which together with the graphically determined terms above listed were used to plot a field of F. The line of frontogenesis found on figure 2 represents the maximum of this field of F.

In discussing this line of frontogenesis Huang says:

> * * * the region of maximum cyclone frequency is quite far removed from the Pacific Polar Front as determined by V. Bjerknes and his coauthors in the book *Physikalische Hydrodynamik*. Actually Richardson's diagram places the storm tracks along the computed frontogenetic line given above, rather than along the deformation axis indicated in the above reference. These two lines represent different things and do not necessarily have to follow each other closely. The deformation axis is formed by the field of motion only, while the frontogenetic line is determined from the frontogenetic function F * * * which has the real importance in determining the zone of frontal activity.
>
> When the two are not coincident with each other as is the case when the maximum $|\nabla\alpha|$ zone does not fall along the deformation axis, or when the angle is such that it does not give a large positive value of F along the axis, the actual frontal activity or the resultant cyclone tracks cannot coincide with the deformation axis of the field of motion. This is just what happens over the Pacific Ocean in the winter season when the cyclonic tracks and the deformation axis denoted in *Physikalische Hydrodynamik* are quite widely separated. The characteristics and the real importance of a frontogenetic line are thus further established by this interesting example.

[1] MONTHLY WEATHER REVIEW, vol. 64, No. 6, pp. 199-203, June 1936.
[2] Contribution to the Theory of Frontogenesis, Sverre Petterssen, Geofysiske Publikationer, vol. XI, No. 6, Oslo 1936.
[3] Mean Monthly Air Transport over the North Pacific Ocean, W. Werenskiold, Geofysiske Publikationer, Vol. II, No. 9, Oslo 1922.

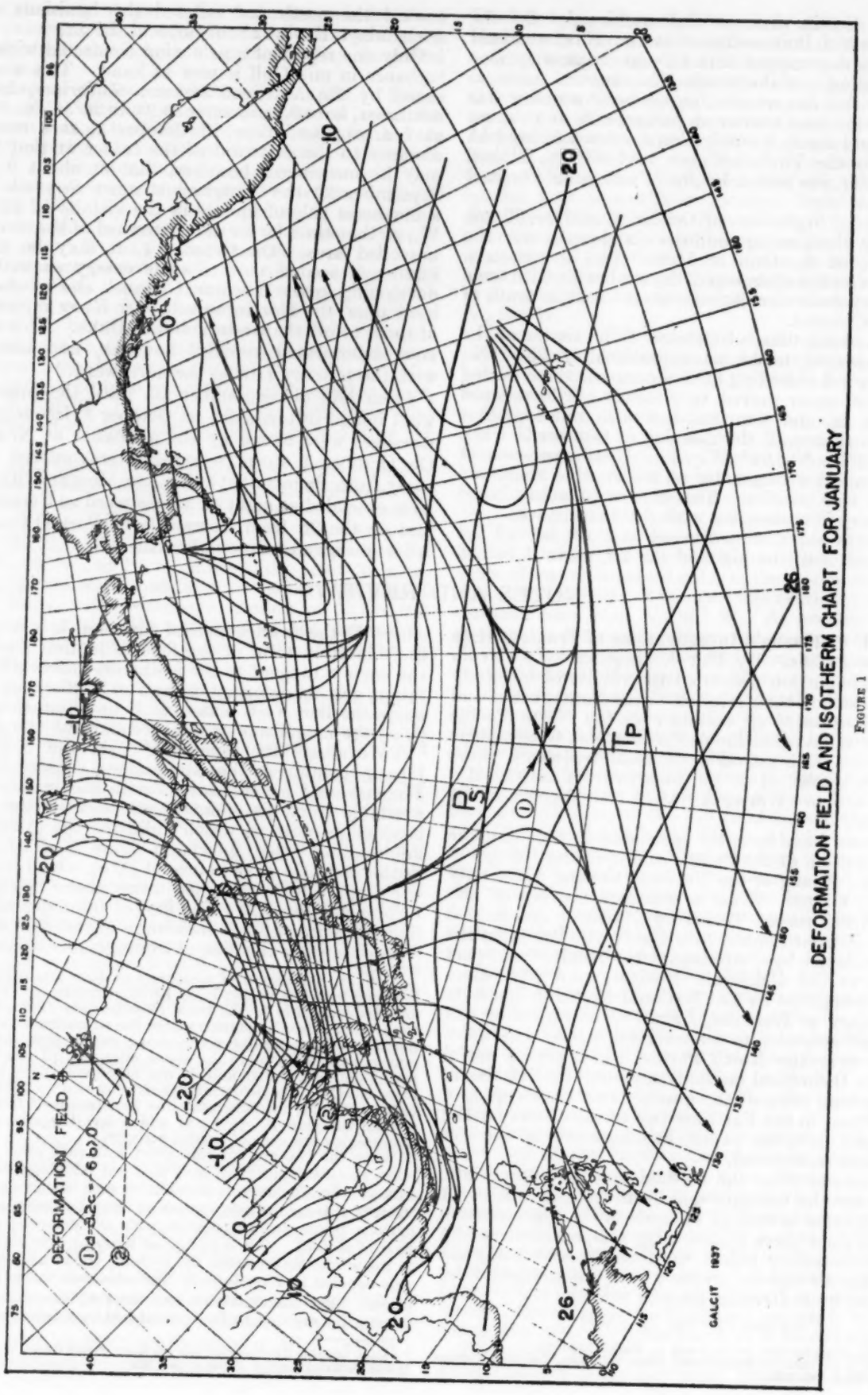
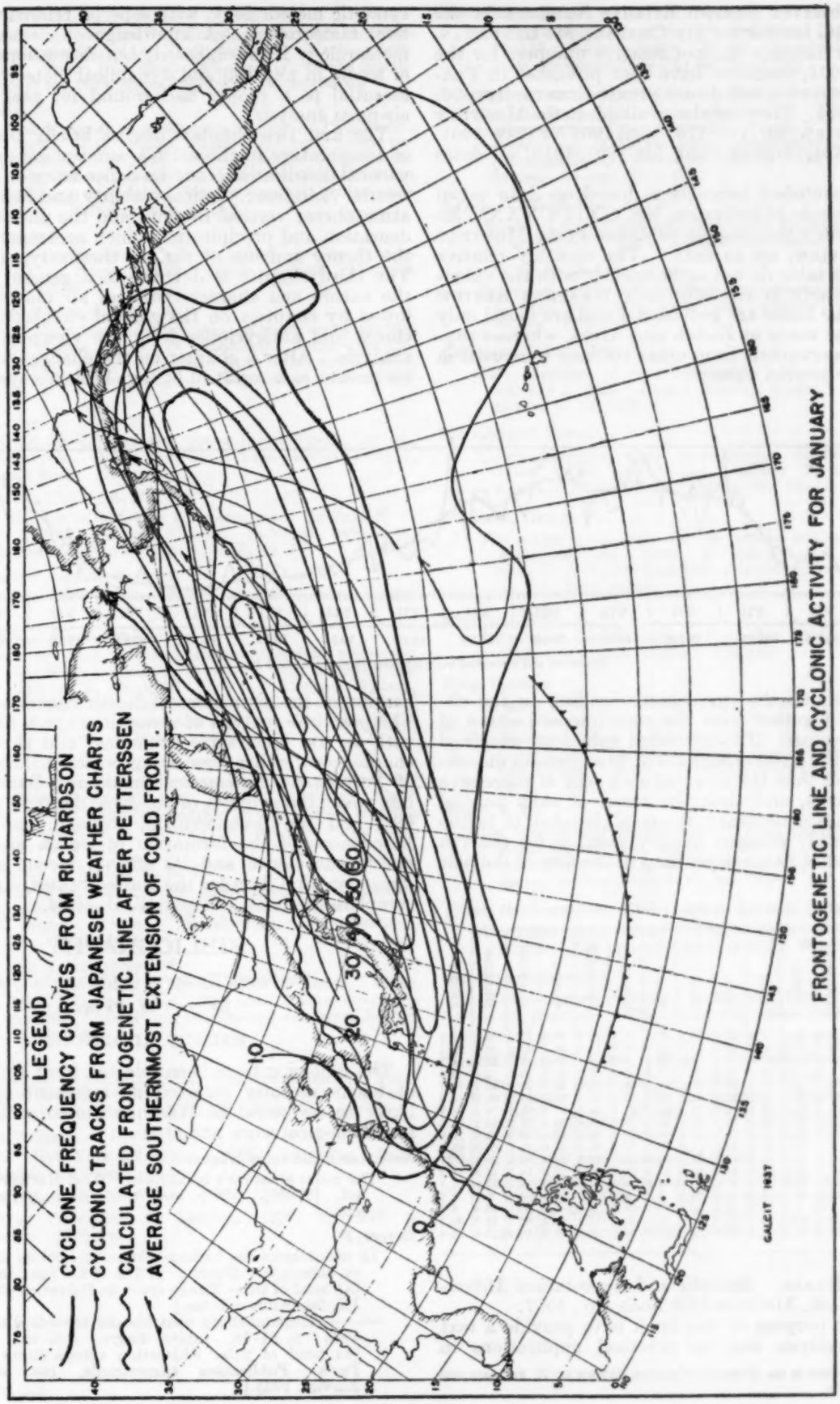

DEFORMATION FIELD AND ISOTHERM CHART FOR JANUARY
DEFORMATION FIELD
①a=-2c-6b>0
②
GALCIT 1937
Ps
Tp
①
②
10
20
0
-10
-20
26

FIGURE 1

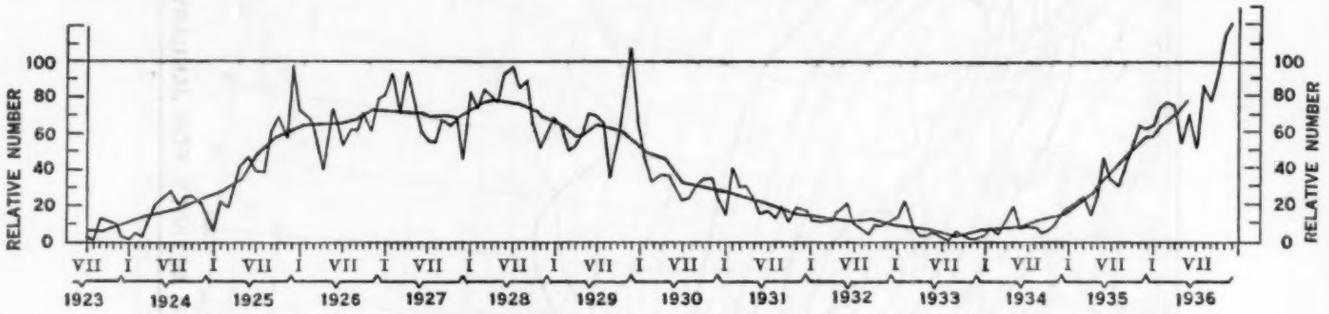


FRONTOGENETIC LINE AND CYCLONIC ACTIVITY FOR JANUARY

FIGURE 2

Monthly Observed Sunspot Relative Numbers for the Period 1920–36, inclusive. By CHARLES M. LENNAHAN. The definitive monthly sunspot relative numbers for the period 1749–1924, inclusive, have been published in TERRESTRIAL MAGNETISM and ATMOSPHERIC ELECTRICITY, 30: 83–86, June 1925. They are also available in the MONTHLY WEATHER REVIEW, 30: 171–176, April 1902 for 1749–1901, and 48: 459–461, August 1920, for 1901–1919, all dates inclusive.

The table published herewith is based on data taken from *Astronomische Mitteilungen*, Nrs. CXII–CXXXV, inclusive, and brings the data, as published in the MONTHLY WEATHER REVIEW, up to date.[1] The monthly relative numbers in the table do not agree exactly with the values published regularly in the MONTHLY WEATHER REVIEW inasmuch as the latter are provisional and are based only on observations made at Zurich and Arosa, whereas supplementary observations from other stations were used in computing the present values.


RELATIVE NUMBER
100
80
60
40
20
0
VII I VII I VII I VII I VII I VII I VII I VII I VII I VII I VII I VII I VII I VII I VII
1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936

Observed and smoothed monthly relative numbers 1923–36.

The graph shows the curve corresponding to the observed values, together with the superimposed curve of the smoothed values. The smoothed values are obtained by first taking the mean of each set of 12 successive monthly numbers, and then the mean of each pair of successive monthly numbers, and then the mean of each pair of successive values so obtained; the result is taken to be the smoothed monthly sunspot relative number for the 7th month in the set of 12 corresponding to the first of the pair of values.

Monthly observed sunspot relative numbers

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1920	51.1	53.9	70.2	14.8	33.3	38.7	27.5	19.2	36.3	49.6	27.2	29.9	37.6
1921	31.5	28.3	26.7	32.4	22.2	33.7	41.9	22.8	17.8	18.2	17.8	20.3	26.1
1922	11.8	26.4	54.7	11.0	8.0	5.8	10.9	6.5	4.7	6.2	7.4	17.5	14.2
1923	4.5	1.5	3.3	6.1	3.2	9.1	3.5	0.5	13.2	11.6	10.0	2.8	5.8
1924	0.5	5.1	1.8	11.3	20.8	24.0	28.1	19.3	25.1	25.6	22.5	16.5	16.7
1925	5.5	23.2	18.0	31.7	42.8	47.5	38.5	37.9	60.2	69.2	58.6	98.6	44.3
1926	71.8	70.0	62.5	38.5	64.3	73.5	52.3	61.6	60.8	71.5	60.5	79.4	63.9
1927	81.6	93.0	69.6	93.5	79.1	59.1	54.9	53.8	68.4	63.1	67.2	45.2	69.0
1928	83.5	73.5	85.4	80.6	76.9	91.4	98.0	83.8	89.7	61.4	50.3	59.0	77.8
1929	68.9	64.1	50.2	52.8	58.2	71.9	70.2	65.8	34.4	54.0	81.1	108.0	65.0
1930	65.3	49.2	35.0	38.2	36.8	28.8	21.9	24.9	32.1	34.4	35.6	25.8	35.7
1931	14.6	43.1	30.0	31.2	24.6	15.3	17.4	13.0	19.0	10.0	18.7	17.8	21.2
1932	12.1	10.6	11.2	11.2	17.9	22.2	9.6	6.8	4.0	8.9	8.2	11.0	11.1
1933	12.3	22.2	10.1	2.9	3.2	5.2	2.8	0.2	5.1	3.0	0.6	0.3	5.7
1934	3.4	7.8	4.3	11.3	19.7	6.7	9.3	8.3	4.0	5.7	8.7	15.4	8.7
1935	18.9	20.5	23.1	12.2	27.3	45.7	33.9	30.1	42.1	53.2	64.2	61.5	36.1
1936	62.8	74.3	77.1	74.9	54.6	70.0	52.3	87.0	76.0	89.0	115.4	123.4	80.4

HORACE R. BYERS. *Synoptic and Aeronautical Meteorology.* New York, McGraw-Hill Book Co., 1937.

The primary purpose of this book is to provide a text on air-mass analysis and its practical applications in synoptic meteorology, with especial reference to aeronautical meteorology. A knowledge of elementary general meteorology is presupposed; but discussions are included of topics in physical and dynamical meteorology that are essential to a proper background for practical work in air-mass analysis.

The first two chapters discuss briefly the distribution of temperature in the earth's atmosphere—especially the vertical distribution—and its dependence on solar and terrestrial radiation; vertical stability and instability in the atmosphere; vertical motions and the phenomena of condensation and precipitation which accompany them; and the theory and use of various thermodynamic diagrams. The third chapter is devoted to a general discussion of the nature and characteristics of air masses, and is followed by chapters on the general circulation and on cyclones and anticyclones from the viewpoint of air-mass analysis. After a chapter on the changes which occur in air masses as a result of lifting, Willett's system of classification of the air masses of North America is presented. The practical analysis of synoptic maps is next discussed, with several illustrative examples; and is followed by a chapter on weather forecasting, which includes an account of Petterssen's kinematical methods. Succeeding chapters cover the subjects of condensation and precipitation; fog; and the thunderstorm, tornado, and waterspout. Discussions of the formation of ice on aircraft, atmospheric turbulence and its effects, recent summaries of upper air wind data for the United States, and duststorms complete the book.—*Edgar W. Woolard.*

BIBLIOGRAPHY

[RICHMOND T. ZOCH, *in Charge of Library*]

By AMY D. PUTNAM

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

American radio relay league.

The radio amateur's handbook. West Hartford, Conn. 14th ed. [c1936]. 536 p. incl. front., illus., ports., diagrs. 24½ cm.

Berger, P.

Le caoutchouc des ballons-pilotes aux points de vue physique et chimique. Zürich. p. 372–388. figs., tables. 23½ cm. [At head of title: Tirage apart de Helvetica physica acta, vol. IX, fasciculus quintus.]

——— Réglement du contrôle des records d'altitude. Paris. 1935. p. 61–68. tables, diagrs. 26½ cm. (Photostated.) [At head of title: Fédération aéronautique internationale. Paris. Publication trimestrielle. 16e année no. 60. Janvier. 1935.]

[1] The numbers published in the MONTHLY WEATHER REVIEW 53: 77, February 1925 are not definitive values.

Blériot, Louis.

Wings over the sea: Are landing places necessary for the commercial aerial crossing of the North Atlantic? Wash. 1936. p. 453–462. plates, fold. diagr. 24½ cm. [From the Smithsonian report for 1935, pages 453–462.] [Pubn. 3370.]

Bossolasco, Mario.

Sulla struttura del vento al suolo nella regione di Mogadiscio. Torino. 1936. 17 p. tables, diagrs. 27½ cm. [Anno polare internationale 1932–1933. Partecipazione italiana sotto gli asupici del Consiglio nazionale delle richerche (Comitato per la geodesia e la geofisica.) Stazione geofisica temporanea di Mogadiscio. Pubblicazione N. 14.]

Braak, C.

The climate of the Netherlands West Indies. 's Gravenhage. [1936.] 120 p. maps, tables, diagrs. 24 cm. [Text in Dutch and English.]

Coblentz, William Weber, & Stair, R.

Evaluation of ultraviolet solar radiation of short wave lengths. (*In* United States Bureau of Standards. Journal of Research. Wash. 1936. 23½ cm. April 1936, v. 16, no. 4, p. 315–347 incl. tables. diagrs.) "References and notes:" p. 346–347.

Cook, Arthur Leroy.

Electric wiring for lighting and power installations. 3d ed., rev. New York. 1933. xiv, 463 p. illus., tables (1 fold.), diagrs. (part fold.) 19 cm.

Cooper, D. LeB., & Linton, E. P.

A note on the use of hot wire anomometers. Halifax, N. S. 1935. p. 120–121. diagr. 22½ cm. [Abstract from Proc. Nova Scotian institute science. v. XIX, pt. 1.]

Cordeiro, Frederick Joaquin Barbosa.

The gyroscope. New York. 1913. vii, 105 p. illus., diagrs. 21 cm.

Craigie, Sir William Alexander, ed.

A dictionary of American English on historical principles, edited by Sir William Craigie . . . with the collaboration of James R. Hulbert . . . George Watson, associate editor, Mitford M. Mathews, assistant editor [and] Allen Walker Read, assistant editor. Chicago. [1936] (Parts 1, 2). 30 cm. Issued in parts.

Cupp, Easter E.

Seasonal distribution and occurrence of marine diatoms and dinoflagellates at Scotch Cap, Alaska. Berkeley, Calif. 1937. p. 71–100. tables, diagrs. 26 cm. [Bull. Scripps inst. of oceanography of the Univ. of Calif., La Jolla, Calif. Tech. ser., v. 4, no. 3.]

Flint, Lewis Herrick, & McAlister, E. D.

Wave lengths of radiation in the visible spectrum promoting the germination of light-sensitive lettuce seed. Wash. 1937. 8 p. pl., diagrs. 24½ cm. (Smithsonian misc. collections, v. 96, no. 2. Pubn. 3414.)

Fuller, Glenn L., & Eakin, Henry M.

The arrest and prevention of devastation by floods. Wash. August 1936. 11 p. table. 22 cm. (Mimeographed.) Given before the Connecticut engineering congress, Bridgeport. July 25, 1936.

Gray, Leslie C.

Air temperature in relation to fire cost and damage. Wash. 1936. p. 779–785. tables, diagrs. 24½ cm. [Reprinted from Journal of forestry, v. XXXIV, no. 8, August 1936.]

Harris, Charles William.

Hydraulics. New York & London. 1936. xiv, 220 p. front. illus., diagrs. 23½ cm.

Heck, Nicholas Hunter.

Earthquakes. Princeton & London. 1936. xi, 222 p. illus., diagrs. 23½ cm.

Hess, Victor F.

Die Ionisierungsbilanz der Atmosphäre. Leipzig. 1934. p. 95–152. tables, diagrs. 24 cm. [Sonderdruck aus Ergebnisse der kosmischen Physik, Band II.]

International meteorological organization. Secretariat.

Les messages synoptiques du temps. Fasc. IV. Météogrammes pour l'Aeronautique. Partie B. Liste des stations synoptiques et des stations supplémentaires du service pour l'aéronautique. Troisième édition. 1937. Leyde. 60 p. tables. 24 cm. [No. 9.]

Jardine, J. T., & Beal, W. H.

Report on the agricultural experiment stations. 1936. Wash. August 1937. 208 p. tables. 23 cm.

Kaye, G. W. C., & Laby, T. H.

Tables of physical and chemical constants, and some mathematical functions. 8th ed. London. [1935.] 162 p. tables. 25½ cm.

Kendrew, Wilfrid George.

The climates of the continents. 3d ed. Oxford. 1937. xii, 473 p. illus. (maps, charts), diagrs. 23 cm. Bibliography: p. 454–457.

Kratochwill, Franz.

Untersuchungen über mehrjährige Niederschlagsperioden. Wien. 1935. p. 181–184. tables. 30 cm. [Wasserwirtschaft und Technik, 2. Jahrg., Nr. 16–17, Juni 10, 1935.]

McEwen, George F.

The water cycle between the ocean, atmosphere, and land. Annapolis, Md. 1936. p. 956–959. 24 cm. [Reprinted from U. S. Naval Institute proceedings, v. 62, no. 7, whole no. 401, July 1936.]

Osorio, Luis H.

Estudios meteorológicos de Colombia 1931 a 1935. [Bogotá] 1936, 118 p. fold. diagrs. 24½ cm.

Puig, Ignacio.

El sol y el cancer. 1ª edicion. Buenos Aires. 1935. 20 p. figs., tables, diagrs. 23 cm. [Publicaciones populares del Observatorio de San Miguel, Serie F. no. 2.]

——— El sol y la tuberculosis. Buenos Aires. 1935. 20 p. figs., diagrs. 23 cm. [Public. pop. del Obser. de San Miguel. Serie F. no. 1.]

Schell, I. I.

On the vertical distribution of wind veolcity over mountain summits. Milton, Mass. 1936. p. 295–300. tables. 23 cm. [Reprinted from the Bulletin of the American met. socy., October 1936, v. 17, no. 10.]

Shaw, Napier.

Unofficial meteorology. Huddersfield. 1934. 26 p. illus., diagrs. 22½ cm. At head of title: Weather studies, no. 1.

[Straits settlements.]

Meteorological branch. Federated Malay states. Government press. 1936. 6 p. col. map. 24½ cm. Appendix XIV.

United States Congress. House. Committee on Military Affairs.

Presenting a medal of honor to General Greely . . . Report . . . [To accompany H. R. 5322.] [Wash. 1935.] 3 p. 24 cm. (74th Cong., 1st sess. House. Rept. 210.)

United States Forest Service. Library.

Precipitation and climate, particularly as they affect the Western States. A bibliography compiled by Library, United States Forest Service . . . Wash. 1935. 16 p. 27 cm. (Mimeographed.)

SOLAR OBSERVATIONS

SOLAR RADIATION OBSERVATIONS DURING SEPTEMBER 1937

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1935 REVIEW, page 24.

Table 1 shows that solar radiation intensities averaged above normal for September at Washington, close to normal at Blue Hill, and below normal at Lincoln and Madison.

Table 2 shows an excess in the amount of total solar and sky radiation received on a horizontal surface at all stations with the exception of Twin Falls, Miami, Riverside, Friday Harbor, and Ithaca.

Polarization measurements made at Madison on 9 days give a mean of 53 percent with a maximum of 60 percent on the 13th. Both of these values are below the corresponding September normals for that station.

TABLE 1.—*Solar radiation intensities during September 1937*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 1	18.59	0.83	0.92	1.02	1.16	------	------	------	------	------	16.79
Sept. 2	19.23	.60	.72	.82	.95	------	------	------	------	------	17.96
Sept. 8	13.13	.66	.75	.84	1.08	------	------	------	------	------	10.97
Sept. 10	13.61	------	.94	1.03	1.17	1.38	------	------	------	------	9.47
Sept. 14	7.32	.74	.80	.93	1.18	------	------	------	------	------	7.04
Sept. 15	10.59	------	.87	.98	1.14	1.40	1.16	0.97	------	------	10.21
Sept. 18	6.50	.91	1.02	1.13	1.24	1.49	------	------	------	------	5.56
Sept. 20	6.27	.91	.99	1.15	1.30	1.46	1.14	.97	0.84	------	6.02
Sept. 23	10.21	------	.70	.78	.93	------	------	------	------	------	10.97
Sept. 24	11.38	------	------	------	1.17	1.46	------	------	------	------	12.68
Sept. 25	10.59	------	------	.91	1.17	1.38	------	------	------	------	12.24
Sept 30	8.48	------	------	.68	.95	------	------	------	------	------	7.87
Means	------	.78	.86	.93	1.12	1.43	(1.15)	(.97)	(.84)	------	------
Departures	------	+.08	+.10	+.06	+.07	+.11	+.08	+.10	+.09	------	------

MADISON, WIS.

Sept. 2	19.23	------	.69	.86	1.03	------	------	------	------	------	18.59
Sept. 3	17.86	------	------	------	------	1.30	------	------	------	------	18.59
Sept. 7	9.83	.68	.76	------	------	------	------	------	------	------	10.59
Sept. 9	10.59	------	.61	.78	1.00	1.30	------	------	------	------	9.83
Sept. 11	9.83	.91	1.00	1.12	1.28	1.42	------	------	------	------	8.18
Sept. 13	7.29	------	.92	------	1.31	------	------	------	------	------	6.50
Sept. 16	5.79	.98	1.08	1.20	1.36	1.56	------	------	------	------	4.75
Sept. 21	5.79	------	.57	.75	.95	------	------	------	------	------	8.18
Sept. 22	11.38	------	.57	.75	.99	------	------	------	------	------	11.81
Sept. 23	12.68	.49	.60	.79	.97	------	------	------	------	------	14.60
Sept. 27	4.75	.60	.76	.89	1.14	1.39	------	------	------	------	4.57
Means	------	.73	.76	.89	1.11	1.39	------	------	------	------	------
Departures	------	−.09	−.13	−.13	−.05	−.01	------	------	------	------	------

[1] Extrapolated

TABLE 1.—*Solar radiation intensities during September 1937*—Con.

LINCOLN, NEBR.

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 2	14.60	0.71	0.86	1.00	1.24	1.45	1.22	1.02	0.89	0.77	10.97
Sept. 3	14.60	.76	.87	1.03	1.16	------	------	------	------	------	14.10
Sept. 10	13.13	------	------	------	------	------	1.29	1.09	.99	.88	9.47
Sept. 11	9.14	.80	.93	1.02	1.27	1.49	------	------	------	------	9.14
Sept. 13	6.76	------	.93	1.08	1.26	1.49	------	------	------	------	6.76
Sept. 14	9.47	.78	.90	.95	1.19	------	------	------	------	------	8.81
Sept. 15	6.50	------	------	------	1.14	1.46	1.15	.93	.72	.64	5.79
Sept. 17	5.16	------	------	.73	1.02	------	1.09	.85	.69	.56	4.57
Means	------	.76	.90	.97	1.18	1.47	1.19	.97	.82	.71	------
Departures	------	−.16	−.12	−.19	−.18	−.06	−.16	−.17	−.18	−.20	------

BLUE HILL, MASS.

Sept. 4	18.2	------	------	------	0.99	1.22	------	------	------	------	19.1
Sept. 6	7.6	------	------	1.10	1.28	1.50	1.20	------	------	------	7.6
Sept. 7	8.6	0.81	0.92	1.05	1.23	1.42	------	------	------	------	7.3
Sept. 8	9.6	------	.90	1.02	1.22	1.46	1.17	1.03	0.91	------	8.6
Sept. 9	7.6	.92	1.03	1.13	1.24	1.37	1.19	1.02	.87	0.74	8.6
Sept. 10	9.6	.84	.94	1.05	1.20	1.43	1.24	1.13	1.03	.93	11.1
Sept. 12	11.9	.74	.86	.99	1.18	1.44	------	------	------	------	10.5
Sept. 14	9.2	------	------	------	------	1.50	1.20	1.06	.96	.86	7.8
Sept. 15	10.5	.62	.72	.93	1.04	1.34	.97	.77	.65	.56	10.2
Sept. 18	6.8	.82	.93	1.05	1.19	1.32	1.21	1.10	1.00	------	6.6
Sept. 20	6.1	.97	1.03	1.10	1.23	1.44	1.25	1.14	1.04	.94	6.2
Sept. 21	5.6	.98	1.04	1.14	1.26	1.50	1.16	1.09	.97	.86	5.4
Sept. 22	7.4	.86	.97	1.09	1.30	1.50	.90	.73	.67	.61	7.5
Sept. 23	9.3	.79	.90	1.04	1.20	1.34	.97	.87	.72	.59	9.5
Sept. 24	11.1	.40	.51	.65	.90	1.19	------	------	------	------	13.7
Sept. 26	13.2	------	------	------	1.06	------	------	------	------	------	12.2
Sept. 30	6.8	------	------	------	1.12	1.39	------	------	------	------	5.2
Means	------	.80	.90	1.03	1.16	1.40	1.13	.99	.88	.76	------
Departures	------	−.01	−.02	−.01	−.02	+.03	.00	+.04	+.02	.00	------

LATE DATA

BLUE HILL, MASS.

Aug. 2	13.7	------	------	------	0.89	1.28	0.80	------	------	------	11.2
Aug. 3	12.7	------	------	------	.99	1.32	1.29	1.08	------	------	10.8
Aug. 4	13.7	------	------	------	.97	1.31	.86	.64	------	------	11.3
Aug. 7	19.5	------	------	------	------	1.33	1.10	------	------	------	18.2
Aug. 11	19.7	------	------	------	------	1.30	1.16	------	------	------	19.1
Aug. 13	16.4	------	------	------	------	1.21	1.14	------	------	------	12.3
Aug. 14	11.5	------	------	------	------	1.40	1.17	1.06	0.96	0.86	9.3
Aug. 15	11.1	0.93	1.03	1.15	1.29	1.49	1.17	.99	.80	.70	9.4
Aug. 16	12.8	------	.69	.85	1.05	1.28	.83	.64	.57	.51	15.1
Aug. 17	16.4	.68	.73	.85	1.05	1.28	------	------	------	------	15.7
Aug. 28	16.4	------	------	------	------	1.26	.96	.80	.70	.56	22.0
Aug. 29	14.7	.71	.80	.90	1.06	1.27	.94	------	------	------	18.0
Aug. 31	18.8	------	------	------	.96	1.09	------	------	------	------	15.8
Means	------	.77	.81	.94	1.03	1.29	1.04	.87	.76	.66	------
Departures	------	+.02	−.01	−.01	−.04	+.02	−.04	−.07	+.04	−.01	------

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca	Newport
	Gram-calories per square centimeter																
1937	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 3	341	486	361	378	372	605	251	493	536	400	352	501	456	630	437	377	427
Sept. 10	456	434	485	376	368	543	183	469	497	388	385	464	353	613	391	234	340
Sept. 17	413	447	472	406	340	531	224	362	390	452	307	407	394	631	291	331	421
Sept. 24	296	291	382	278	305	481	145	401	314	235	411	381	319	513	183	327	315
	Departures from weekly normals																
Sept. 3	−40	+107	−93	+37	+54	+31	+55	+17	.....	−31	−61	−5	0	.....	+7	+38	.....
Sept. 10	+87	+95	+55	+76	+51	−2	−27	+14	.....	−32	+51	−3	−87	.....	+36	−99	.....
Sept. 17	+44	+100	+48	+87	+38	+135	+66	−46	.....	+19	−1	−14	−29	.....	−35	+1	.....
Sept. 24	−54	−1	+8	+12	+25	+114	+19	−28	.....	−150	+53	−34	−81	.....	−146	+25	.....
	Accumulated departures on—																
	+2,261	+8,050	+3,808	+5,334	+6,118	+7,833	+1,428	+336	.....	−9,184	+4,935	−3,780	−2,709	.....	−1,617	−4,676	.....

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.), Superintendent, U. S. Naval Observatory. Data furnished by the U. S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. The difference in longitude is measured from the central meridian, positive west. The north latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups]

Date	Eastern standard time	Mt. Wilson group number	Heliographic: Diff. in longitude	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day	Observatory
1937	h. m.		°	°	°				
Sept. 1	11 27	5540	−60.0	194.4	+19.0	.....	242	.....	U. S. Naval.
		5543	−60.0	194.4	−11.0	.....	24	.....	
		5542	−34.0	220.4	+6.5	.....	48	.....	
		5538	−17.0	237.4	+30.0	.....	436	.....	
		5536	+31.0	285.4	−12.5	.....	73	.....	
		5533	+75.0	329.4	+13.0	.....	48	.....	
		5522	+86.0	340.4	+33.0	.....	485	1,356	
Sept. 2	11 8	5540	−51.0	190.4	+14.0	6	.....	.....	Do.
		5540	−48.0	193.4	+19.0	.....	242	.....	
		5543	−48.0	193.4	−12.0	16	.....	.....	
		5538	−4.0	237.4	+29.5	.....	339	.....	
		5542	+21.0	262.4	+6.5	.....	36	.....	
		5545	+40.5	281.9	+6.0	.....	12	.....	
		5536	+43.0	284.4	−14.0	.....	194	845	
Sept. 3	10 59	5548	−79.0	149.2	+10.0	339	.....	.....	Do.
		5540	−40.0	188.2	+14.0	.....	12	.....	
		5540	−35.0	193.2	+19.0	.....	242	.....	
		5543	−34.0	194.2	−12.0	16	.....	.....	
		5538	+3.0	231.2	+32.5	.....	145	.....	
		5538	+11.0	239.2	+27.0	.....	170	.....	
		5546	+12.0	240.2	−8.0	12	.....	.....	
		5545	+52.0	280.2	+6.0	12	.....	.....	
		5536	+59.0	287.2	−14.0	.....	218	1,166	
Sept. 4	9 5	5548	−67.0	149.1	+10.5	436	.....	.....	Mt. Wilson.
		5540	−27.0	189.1	+13.0	.....	12	.....	
		5540	−23.0	193.1	+18.5	.....	145	.....	
		5543	−21.5	194.6	−12.0	12	.....	.....	
		5549	−2.5	213.6	−10.0	.....	24	.....	
		5538	+15.0	231.1	+33.0	.....	121	.....	
		5538	+24.0	240.1	+27.0	.....	145	.....	
		5545	+64.0	280.1	+6.0	12	.....	.....	
		5536	+70.0	286.1	−14.0	.....	145	1,052	
Sept. 5	9 35	5548	−66.0	136.6	+11.0	36	.....	.....	Do.
		5548	−53.0	149.6	+11.0	.....	436	.....	
		5540	−11.0	191.6	+13.0	.....	48	.....	
		5540	−9.0	193.6	+18.5	.....	97	.....	
		5549	+12.5	215.1	−11.0	.....	48	.....	
		5538	+28.5	231.1	+33.0	.....	48	.....	
		5538	+35.0	237.6	+27.0	.....	97	810	
Sept. 6	9 15	5551	−82.0	107.6	+13.5	4	8	.....	Do.
		5548	−52.0	137.6	+11.0	.....	48	.....	
		5548	−39.0	150.6	+11.0	.....	436	.....	
		5540	+2.0	191.6	+13.0	.....	48	.....	
		5540	+4.0	193.6	+18.5	.....	73	.....	
		5543	+5.0	194.6	−13.0	.....	12	.....	
		5549	+20.5	210.1	−10.0	.....	18	.....	
		5550	+21.0	210.6	+10.5	.....	194	.....	
		5538	+43.0	232.6	+34.0	.....	48	.....	
		5538	+51.0	240.6	+27.0	.....	73	998	
Sept. 7	15 16	5551	−68.0	105.1	+12.0	.....	436	.....	U. S. Naval.
		5553	−50.5	122.6	+19.0	36	.....	.....	
		5552	−43.0	130.1	+10.0	.....	48	.....	
		5548	−34.0	139.1	+10.0	.....	73	.....	
		5548	−22.0	151.1	+11.0	.....	485	.....	
		5540	+21.0	194.1	+18.0	.....	48	.....	
		5550	+38.0	211.1	+10.5	.....	170	1,296	

Positions and areas of sun spots—Continued

Date	Eastern standard time	Mt. Wilson group number	Heliographic: Diff. in longitude	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day	Observatory
1937	h. m.		°	°	°				
Sept. 8	11 2	5551	−56.0	106.2	+12.0	.....	727	.....	Do.
		5553	−39.5	122.7	+19.0	.....	73	.....	
		5552	−32.0	130.2	+10.0	.....	97	.....	
		5548	−22.0	140.2	+9.5	.....	73	.....	
		5548	−11.0	151.2	+10.0	.....	485	.....	
		5540	+33.0	195.2	+18.0	.....	48	.....	
		5550	+50.0	212.2	+10.0	.....	194	1,697	
Sept. 9	11 4	5551	−43.0	106.0	+12.0	.....	582	.....	Do.
		5553	−26.0	123.0	+19.5	.....	85	.....	
		5552	−19.0	130.0	+10.0	.....	97	.....	
		5548	−9.0	140.0	+9.5	.....	73	.....	
		5548	+2.0	151.0	+10.5	.....	485	.....	
		5540	+45.0	194.0	+17.0	.....	24	.....	
		5550	+63.0	212.0	+8.0	.....	436	1,782	
Sept 10	11 7	5551	−30.0	105.7	+12.0	.....	485	.....	Do.
		5554	−11.0	124.7	−11.0	.....	145	.....	
		5553	−10.0	125.7	+19.0	.....	61	.....	
		5552	−5.0	130.7	+10.0	.....	194	.....	
		5548	+5.0	140.7	+9.5	.....	73	.....	
		5548	+15.0	150.7	+10.5	.....	533	.....	
		5540	+58.0	193.7	+13.5	.....	24	.....	
		5550	+76.0	211.7	+8.0	.....	485	2,000	
Sept. 11	12 26	(†)	−51.5	70.3	+11.0	12	.....	.....	Do.
		5551	−16.0	105.8	+12.0	.....	388	.....	
		5554	+3.5	123.3	−10.5	.....	97	.....	
		5553	+3.5	125.3	+19.0	.....	73	.....	
		5552	+9.5	131.3	+11.0	.....	436	.....	
		5548	+21.0	142.8	+9.5	.....	24	.....	
		5548	+29.0	150.8	+10.5	.....	776	1,806	
Sept. 12	12 31	5556	−80.0	28.6	+17.5	145	.....	.....	Do.
		5555	−78.0	30.6	+12.0	.....	291	.....	
		5551	−2.0	106.6	+13.0	.....	242	.....	
		5553	+18.5	127.1	+19.0	.....	48	.....	
		5554	+19.0	127.6	−12.0	.....	61	.....	
		5552	+24.0	132.6	+12.0	.....	485	.....	
		5548	+33.0	141.6	+9.5	.....	12	.....	
		5548	+43.0	151.6	+10.5	.....	776	2,060	
Sept. 13	11 10	5556	−69.0	27.1	+18.0	145	.....	.....	Do.
		5555	−66.0	30.1	+13.0	.....	339	.....	
		5551	+11.0	107.1	+13.0	.....	242	.....	
		5554	+29.5	125.6	−11.0	.....	61	.....	
		5553	+31.0	127.1	+20.0	36	.....	.....	
		5552	+36.0	132.1	+12.0	.....	970	.....	
		5548	+48.0	144.1	+9.5	24	.....	.....	
		5548	+56.0	152.1	+11.0	.....	679	2,496	
Sept. 14	11 14	5557	−65.0	17.9	−20.5	48	.....	.....	Do.
		5556	−56.0	26.9	+18.0	48	.....	.....	
		5555	−53.0	29.9	+13.0	.....	242	.....	
		5551	+24.0	106.9	+13.0	.....	97	.....	
		5553	+44.0	126.9	+20.0	24	.....	.....	
		5552	+50.0	132.9	+12.0	.....	1454	.....	
		5548	+60.0	142.9	+10.0	24	.....	.....	
		5548	+69.0	151.9	+12.0	.....	679	2616	
Sept. 15	11 6	5557	−50.0	19.7	−20.0	61	.....	.....	Do.
		5556	−46.0	23.7	+15.0	.....	97	.....	
		5555	−38.0	31.7	+12.0	.....	194	.....	
		5551	+39.0	108.7	+11.0	.....	73	.....	
		5553	+58.0	127.7	+19.0	24	.....	.....	
		5552	+64.0	133.7	+11.0	.....	1309	.....	
		5548	+85.0	154.7	+11.0	582	.....	2,340	

† Not numbered.

Positions and Areas of Sun Spots—Continued

Date	Eastern standard time	Mt. Wilson group number	Heliographic			Area		Total area for each day	Observatory
			Diff. in longitude	Longitude	Latitude	Spot	Group		
1937	h. m.		°	°	°				
Sept. 16	11 56	5560	−88.0	328.1	+32.0	194			Do.
		5558	−70.0	346.1	+15.0	36			
		5559	−41.5	14.6	−28.0	12			
		5557	−36.0	20.1	−20.0	73			
		5556	−33.0	23.1	+16.0		145		
		5555	−25.0	31.1	+11.0		242		
		5551	+52.5	108.6	+11.0		97		
		5553	+70.0	126.1	+19.0		24		
		5552	+78.0	134.1	+11.0		1,212	2,035	
Sept. 17	15 30	5560	−73.0	327.8	+32.0	194			Do.
		5558	−55.0	345.8	+16.0	12			
		5557	−20.5	20.3	−20.0	61			
		5556	−17.0	23.8	+16.0		73		
		5555	−9.0	31.8	+11.0		145		
		5561	−3.0	37.8	−6.0	12		497	
Sept. 18	11 5	5565	−70.0	320.1	−22.0	6			Do.
		5560	−62.0	328.1	+32.0	291			
		5558	−42.5	347.6	+16.5	24			
		5564	−26.0	4.1	+12.0		109		
		5557	−10.0	20.1	−20.0	61			
		5556	−2.0	28.1	+16.0		73		
		5555	+3.0	33.1	+12.0		242		
		5561	+9.0	39.1	−7.0		121	927	
Sept. 19	9 11	5565	−57.0	321.0	−22.0	12			Mt. Wilson.
		5560	−50.5	327.5	+33.0	291			
		5558	−31.0	347.0	+18.0		36		
		5564	−11.0	7.0	+12.0		242		
		5557	+3.0	21.0	−19.5	73			
		5556	+11.0	29.0	+17.0		48		
		5555	+15.0	33.0	+12.0		170		
		5563	+22.5	40.5	+6.0		48		
		5561	+24.0	42.0	−5.0		73	993	
Sept. 20	11 20	5566	−73.0	290.6	−13.0	97			U. S. Naval.
		5560	−37.0	326.6	+33.0	291			
		5558	−18.0	345.6	+16.0		24		
		5564	+3.0	6.6	+12.0		291		
		5557	+17.0	20.6	−20.0	48			
		5555	+29.0	32.6	+11.0		194		
		5563	+36.0	39.6	+5.0		97		
		5561	+40.0	43.6	−5.0		48	1,090	
Sept. 21	11 5	5566	−59.0	291.5	−13.0	48			Do.
		5568	−59.0	291.5	+12.0	6			
		5558	−3.0	347.5	+16.0		24		
		5567	+13.0	3.5	−15.0		12		
		5564	+17.0	7.5	+12.0		218		
		5560	+24.5	15.0	+33.0	218			
		5557	+29.0	19.5	−21.0	24			
		5555	+42.0	32.5	+11.0		145		
		5563	+50.0	40.5	+4.0		48	743	
Sept. 22	11 26	5571	−80.0	257.2	+20.0	6			Do.
		5570	−71.0	266.2	+11.0	6			
		5568	−48.0	289.2	+12.0		73		
		5566	−45.0	292.2	−13.0	48			
		5560	−12.0	325.2	+33.0	206			
		5569	+9.0	346.2	−22.0		24		
		5558	+9.5	346.7	+17.0		12		
		5567	+28.0	5.2	−16.0		145		
		5564	+30.0	7.2	+12.0		218		
		5557	+41.0	18.2	−21.0	24			
		5555	+52.0	29.2	+9.5	97		859	
Sept. 23	11 7	5572	−74.0	250.1	+17.0	145			Do.
		5571	−66.0	258.1	+19.0		48		
		5570	−60.0	264.1	+11.0		97		
		5568	−33.0	291.1	+12.0		73		
		5566	−31.0	293.1	−13.0	48			
		5560	−0.5	323.6	+33.0	218			
		5569	+20.0	344.1	−23.0		48		
		5558	+25.0	349.1	+15.0		6		
		5567	+41.0	5.1	−16.0		242		
		5564	+43.0	7.1	+11.0		242		
		5557	+56.0	20.1	−20.5	12			
		5555	+65.0	29.1	+10.0		48	1,227	
Sept. 24	11 7	5572	−63.0	247.9	+17.0		218		Do.
		5571	−52.0	258.9	+20.0	12			
		5570	−47.0	263.9	+11.0		97		
		5574	−29.0	281.9	−11.0		36		
		5566	−19.0	291.9	−12.0	24			
		5560	+12.0	322.9	+33.0	218			
		5568	+19.0	329.9	+12.0	48			
		5569	+32.0	342.9	−22.5		48		
		5567	+55.0	5.9	−16.5		388		
		5564	+57.0	7.9	+11.0		339		
		5555	+80.0	30.9	+10.0	48		1,476	
Sept. 25	11 22	5572	−50.0	247.6	+17.0		218		Do.
		5575	−39.5	258.1	+38.5		48		
		5571	−39.0	258.6	+19.5	36			
		5570	−33.0	264.6	+11.5		97		
		5574	−15.0	282.6	−10.0		97		
		5568	−5.0	292.6	+11.0	48			
		5560	+25.0	322.6	+34.0	194			

Positions and Areas of Sun Spots—Continued

Date	Eastern standard time	Mt. Wilson group number	Heliographic			Area		Total area for each day	Observatory
			Diff. in longitude	Longitude	Latitude	Spot	Group		
1937	h. m.		°	°	°				
Sept. 25	11 22	5573	+34.0	331.6	−20.0		12		
		5569	+45.0	342.6	−23.0	6			
		5567	+69.0	6.6	−17.0		533		
		5564	+70.0	7.6	+11.0		291	1,580	
Sept. 26	11 28	5576	−73.0	211.3	−22.0	12			Mt. Wilson.
		5572	−33.0	251.3	+17.0	200			
		5575	−27.0	257.3	+39.0		97		
		5571	−25.0	259.3	+19.0		24		
		5570	−21.0	263.3	+12.0		97		
		5574	−2.0	282.3	−10.0		97		
		5568	+8.0	292.3	+12.0	85			
		5560	+36.0	320.3	+35.0	194			
		5573	+46.0	330.3	−20.5		12		
		5567	+78.0	2.3	−18.0	145		963	
Sept. 27	9 40	5577	−82.0	190.1	−12.0		48		Do.
		5572	−20.0	252.1	+17.0	200			
		5571	−15.0	257.1	+21.0		48		
		5575	−14.0	258.1	+39.5		109		
		5570	−7.0	265.1	+12.0		73		
		5574	+11.0	283.1	−10.5	85			
		5568	+22.0	294.1	+12.0	16			
		5560	+48.0	320.1	+34.0	194		773	
Sept. 28	12 47	5578	−80.0	177.2	+10.0		582		Do.
		5579	−79.0	178.2	−18.0	145			
		5577	−69.0	188.2	−13.0		194		
		5572	−7.0	250.2	+17.0	194			
		5575	−4.0	253.2	+39.5		170		
		5571	0.0	257.2	+19.0		36		
		5570	+6.0	263.2	+12.5		145		
		5574	+23.0	280.2	−10.5	48			
		5568	+36.0	293.2	+12.5	16			
		5560	+62.0	319.2	+34.0	194		1,724	
Sept. 29	11 20	5578	−65.0	179.8	+9.5		970		U. S. Naval.
		5579	−61.0	183.8	−18.0	121			
		5577	−54.0	190.8	−11.0		145		
		5576	−33.0	211.8	−21.0	6			
		5572	+6.0	250.8	+17.0	194			
		5575	+9.5	254.3	+39.5		170		
		5571	+11.0	255.8	+21.0	12			
		5570	+20.0	264.8	+13.0		121		
		5574	+37.0	281.8	−11.0	12			
		5560	+72.0	316.8	+32.0	194		1,945	
Sept. 30	11 10	5581	−80.0	151.7	+11.0	242			Do.
		5578	−52.0	179.7	+10.0		1,454		
		5579	−49.5	182.2	−18.0	48			
		5577	−42.0	189.7	−12.0		145		
		5572	+19.0	250.7	+17.0	194			
		5575	+21.0	252.7	+39.5		145		
		5571	+26.0	257.7	+19.0	24			
		5570	+33.0	264.7	+12.0		73		
		5560	+86.0	317.7	+33.0	145		2,470	

Mean daily area for 30 days=1,454.

PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR SEPTEMBER 1937

[Dependent alone on observations at Zurich and its station at Arosa]

[Furnished through the courtesy of Prof. W. Brunner, Eidgen, Sternwarte, Zurich, Switzerland]

September 1937	Relative numbers	September 1937	Relative numbers	September 1937	Relative numbers
1	109	11	*a* —	21	73
2	*a* 110	12	*d* 101	22	*Wcd* —
3	*d* 127	13	110	23	—
4	82	14	101	24	*a* 120
5	*Ec* 79	15	99	25	*Ec* 127
6	*Mac* 85	16	76	26	74
7	*Ecd* 101	17	*d* 58	27	80
8	104	18	*Mac* 82	28	*ad* 101
9	*a* 119	19	*Mc* 88	29	*aa* 126
10	*a* —	20	*a* 88	30	*d* 121

Mean, 26 days=97.7.

a=Passage of an average sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a group developing into a middle sized or large center of activity: *E:* on the eastern part of the sun's disc, *W:* on the western part, *M:* in the central circle zone.
d=Entrance of a large or average sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE, in Charge]

By L. P. HARRISON

Mean free-air data based on airplane weather observations during the month of September 1937 are given in tables 1 to 3. A description of the methods by which the various monthly means and normals therein are computed may be found in the aerological section of the MONTHLY WEATHER REVIEW for January and March 1937.

It will be noted that many of the "normals" are based on only 3 years of observation. Conclusions based on departures from such short-period "normals" must be used with caution.

The mean surface temperatures for September (see chart I) were generally above normal in the western two-thirds of the country and below normal in the eastern third except for small areas in the extreme southeast, and northeast. The positive departures in the west averaged about 2° C., while the departures of opposite sign in the east averaged about −1° C. The small areas last referred to had departures mostly less than +0.8° C.

The mean free-air temperatures for the month up to 5 kilometers were generally below normal over the country with the exception of the extreme southwest, possibly the central part of the Western Plateau Region, and the eastern Gulf States at high levels (Pensacola 3 to 5 kilometers only). Negative departures were most marked in the northeastern sector of the country, especially near the Great Lakes and the middle Atlantic coast, as exemplified by the data for Chicago, Selfridge Field, Wright Field, Lakehurst, Washington, D. C., and Norfolk where the greatest departure was −3.2° C., but the average nearly −2° C. This regime of subnormal temperatures appeared to be associated with the similar one observed near the surface in south-central Canada and eastern United States. Over the extreme northwest the negative departures were also appreciable at the higher elevations (−2.3° C. at 5 kilometers near Spokane). Elsewhere the negative departures were mostly slight (near 1° C. or less). The positive departures which occurred were only of consequence at low or moderate elevations over the extreme southwest and the central plateau regions, with the greatest values +2.2° C. near San Diego at 1.5 kilometers, and +1.8° C. near Cheyenne at 2 kilometers, but the average values appreciably less.

The mean free-air relative humidities and specific humidities are given in table 2. Generally speaking, the relative humidities did not depart greatly from the normal over most of the country. However, they were largely subnormal to a moderate extent (−5 to −9 percent) over the middle Atlantic and east Gulf coastal areas, particularly at the moderate and higher elevations (2 or 3 to 5 kilometers), and to a slightly greater extent over the south-central part of the country at the lower elevations. This was most marked near San Antonio, Tex. (−15 to −11 percent). The northern Great Plains also had moderately subnormal humidities near the surface. In the area restricted to the extreme southwest at 3 kilometers and extending over perhaps the entire southwestern sector of the country at 5 kilometers, notably above-normal humidities prevailed. The maximum departures occurred at the latter height, viz: +14 percent, San Diego; +8 percent, El Paso; +11 percent, San Antonio; +11 percent, Cheyenne. Values moderately in excess of the normal were also found at the same elevation over the north-central portion of the country. At lower elevations the departures were generally considerably smaller.

Table 3 shows the monthly mean free-air barometric pressures and equivalent potential temperatures. The lowest mean barometric pressures in continental United States prevailed over the Great Lakes, with the minima mostly near Sault Ste. Marie, Mich., or slightly to the west, and the highest prevailed over the extreme southern part of the country, with no distinct center of concentration for the maximum values. The trend of the mean free-air isobars was generally west to east, with a tendency for slight cyclonic curvature in the northern part of the country. The average pressure gradients were practically everywhere of weak intensity.

Table 4 shows the free-air resultant winds based on pilot-balloon observations made near 5 a. m. (75th meridian time) during September. The resultant winds were near normal in direction and slightly below normal in velocity, with a few exceptions. Not mentioning cases with very small resultant velocities, the month's resultant wind directions at stations along the middle and south Pacific coastal area were oriented from about 35° to, in one instance, 160° counterclockwise from normal, that is, with southerly replacing westerly directions to some extent. At 3 kilometers near Seattle, a clockwise orientation with respect to the normal of about 60° occurred (i. e., N replacing NW). In the vicinity of the coast of the Gulf of Mexico some abnormal resultant directions also predominated, as exemplified by the data for Houston (60° to 85° counterclockwise from normal from 2 to 3 kilometers), Pensacola (32° to 140° counterclockwise), and Key West (nearly 20° counterclockwise up to 2 kilometers, 115° to 160° clockwise at 2.5 and 3 kilometers respectively); or generalizing, northeast or north replacing southeast or east directions in the former two cases, and southwest or west replacing southeast in the latter case at the higher elevations referred to.

Table 5 shows the maximum free-air wind velocities and their directions for various sections of the United States during September as determined by pilot balloon observations. The extreme maximum was 50 m. p. s. from the west-southwest at 11,560 meters above sea level over Rock Springs, Wyo.

The mean monthly specific humidities and equivalent potential temperatures are shown in tables 2 and 3 respectively. With respect to both these elements, the minima occurred near the Great Lakes, and the maxima near the extreme southeastern portion of Western Plateau, with center in the vicinity of El Paso. The curl of the lines of constant value of the elements in question thus gave evidence of a mean anticyclonic trajectory of the air from the Pacific southwest coast over the southern portion of the plateau, and of a less marked cyclonic trajectory from southwestern Canada over the northern, especially northeastern, part of the United States.

During September the eastern third of the country was largely dominated by rather extensive anticyclones of Pc origin which entered the country mostly from south-central Canada. The invasions of the relatively cool and dry air masses from the north and northwest tended to block off to a considerable extent and more frequently than normal the customary alternating outbreaks of warm, moist, air from the Gulf of Mexico and the tropical Atlantic Ocean. These conditions gave rise to the occurrence of subnormal temperatures in the East as already indicated and to the pressure of relatively dry air over

the Gulf and thence also over the south central part of the country at the lower elevations under the influence of the prevailing circulation. On several occasions, disturbances along fronts formed between advancing Pc air masses and opposing TA air in the lower Mississippi Valley were there conduicve to normal or excessive precipitation (100–200 percent). Most of the eastern third of the country had deficient precipitation (25 to 80 percent of normal), except along the east Florida and the New England coastal areas where the rainfall was approximately normal or somewhat in excess of normal.

The western half of the country was for a considerable period of the month under the dominance of successive anticyclones of PP origin. Subsidence with attendant low relative humidities was rather widespread in the PP air masses thus passing over the Western Plateau; and a pronounced abnormal transport of air occurred at moderate and higher elevations from the south or southwest across the central or south Pacific coast as a consequence of the high pressure distribution. The circulation from the Gulf of Mexico also on a number of occasions brought moist and fairly warm air into the southern portion of the plateau. This was, therefore, a center of high moisture content, moderate or low relative humidities but depressed isentropic surfaces. These conditions in conjunction with the sunshine prevalent during the anticyclonic clear skies were effective in producing abnormally warm weather over a considerable area in the West.

However, they were also effective in bringing about marked deficiency in precipitation over a large fraction of the same area, especially along the Pacific coast and the northern Great Plains, with the average in the latter section about 60 percent of normal, although the rainfall was near normal in the southeastern part of the plateau.

Along the northern border section of the country where the moist air from over the southern plateau had an opportunity to reach condensation levels and ascend to considerable elevations up the slopes of the isentropic and equivalent potential temperature surfaces in the advancing Pc (and occasionally PP) air masses, the rainfall was generally close to normal or excessive in restricted areas, particularly Michigan and Montana.

TABLE 1.—*Mean free-air temperatures (t), °C obtained by airplanes during September 1937. (Dep. represents departure from "normal" temperature)*

Station	Number of obs.	Altitude (meters) m. s. l.																	
		Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000	
		t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.
Barksdale Field [1] (Shreveport), La. (52 m)	30	20.2	−0.8	22.8	−0.2	20.0	−0.3	17.3	−0.2	14.4	−0.4	11.7	−0.4	9.0	−0.5	3.2	−0.6	−1.8	−0.1
Billings, Mont.[2] (1,090 m)	20	12.8	+1.0	------	------	------	------	14.4	+0.5	11.0	−0.2	7.9	−0.2	4.2	−0.4	−3.7	−1.4	−10.7	−2.1
Boston, Mass.[1] (5 m)	28	13.7	------	14.6	------	11.9	------	9.9	------	8.4	------	6.9	------	4.7	------	−0.3	------	−5.3	------
Cheyenne, Wyo.[2] (1,873 m)	30	10.6	+1.7	------	------	------	------	------	------	13.0	+1.8	13.2	+1.4	10.0	+1.2	2.0	+0.2	−6.0	−0.4
Chicago, Ill.[3] (187 m)	30	14.1	−0.7	15.9	−0.7	12.9	−2.3	9.9	−2.7	8.0	−2.4	5.7	−2.2	3.2	−2.0	−2.7	−1.9	−8.3	−1.5
Coco Solo, Canal Zone [3] (15 m)	27	24.5	------	23.5	------	21.0	------	18.3	------	15.6	------	12.9	------	10.2	------	4.1	------	−1.7	------
El Paso, Tex.[2] (1,194 m)	30	20.2	+0.9	------	------	------	------	21.3	+0.8	18.6	+0.4	15.2	+0.1	11.3	−0.4	3.8	−0.7	−2.6	−0.7
Fargo, N. Dak.[3] (247 m)	29	11.3	+0.6	13.8	+0.2	12.8	+0.3	10.7	+0.2	8.7	+0.5	5.7	+0.1	2.8	+0.1	−3.4	−0.2	−9.8	−0.7
Kelly Field (San Antonio), Tex.[1] (206 m)	30	22.2	+0.6	23.2	+0.8	21.1	+0.5	18.1	+0.1	14.9	−0.3	11.9	−0.8	9.1	−0.9	3.0	−1.2	−3.0	−1.0
Lakehurst, N. J.[3] (39 m)	26	13.1	−0.7	15.0	−0.3	12.4	−0.4	10.4	−0.8	8.7	−0.8	5.8	−1.6	2.8	−2.1	−3.2	−3.2	------	------
Maxwell Field (Montgomery), Ala.[1] (52 m)	27	20.7	+0.3	20.5	−1.4	18.1	−1.5	15.9	−1.1	13.6	−1.1	10.4	−1.5	8.1	−1.1	3.1	−0.4	−2.2	+0.2
Mitchel Field (Hempstead, L. I.), N. Y.[1] (29 m)	24	13.9	−1.1	14.6	−1.0	12.6	−1.0	10.8	−1.2	9.5	−0.6	7.5	−0.7	4.9	−0.7	−1.1	−1.3	------	------
Nashville, Tenn.[2] (180 m)	29	16.9	−0.9	19.0	−1.2	16.8	−1.4	14.3	−1.1	12.4	−0.6	10.1	−0.2	7.6	0.0	1.9	+0.1	−4.2	+0.2
Norfolk, Va.[3] (10 m)	24	18.8	−2.8	18.1	−2.5	14.9	−3.2	13.1	−2.5	11.4	−1.8	9.5	−1.1	7.1	−1.0	1.9	−0.7	−3.5	−0.5
Oakland, Calif.[3] (2 m)	30	14.3	------	17.0	------	19.2	------	17.6	------	15.0	------	11.8	------	8.9	------	2.7	------	−4.6	------
Oklahoma City, Okla.[2] (391 m)	30	19.1	+0.3	20.4	+0.7	21.3	+1.4	18.8	+1.1	16.0	+0.8	12.8	+0.6	9.5	+0.3	2.9	+0.1	−3.9	−0.3
Omaha, Nebr.[2] (300 m)	29	16.2	+0.6	17.9	+0.6	17.4	−0.9	15.1	−1.3	12.7	−1.3	9.8	−1.3	6.8	−1.3	0.3	−1.4	−5.9	−1.1
Pearl Harbor, Hawaii [3] (6 m)	30	22.6	−1.6	22.0	+0.2	18.6	+0.5	16.0	+0.9	13.3	+0.7	12.2	+1.0	10.4	+1.1	6.4	+2.4	1.0	+2.1
Pensacola, Fla.[3] (13 m)	28	20.9	−2.1	21.8	−0.6	19.2	−0.6	16.7	−0.4	13.6	−0.7	11.4	−0.3	9.3	+0.4	4.0	+0.9	−1.6	+0.9
St. Thomas, Virgin Islands [3] (8 m)	30	29.4	------	25.0	------	21.8	------	19.1	------	16.7	------	14.2	------	11.6	------	6.4	------	1.6	------
Salt Lake City, Utah [2] (1,288 m)	30	14.6	------	------	------	------	------	19.2	------	17.4	------	13.9	------	10.2	------	2.7	------	−4.4	------
San Diego, Calif.[3] (10 m)	29	18.8	−0.3	18.6	+1.2	22.1	+2.1	21.4	+2.2	19.1	+1.5	15.9	+1.2	12.5	+0.9	5.6	+0.6	−1.2	+0.1
Sault Ste. Marie, Mich.[2] (221 m)	30	11.3	------	11.8	------	9.7	------	7.3	------	5.1	------	2.8	------	0.2	------	−5.4	------	−11.4	------
Scott Field (Belleville), Ill.[1] (135 m)	27	13.8	−1.6	17.5	−1.8	15.6	−2.1	13.1	−2.1	11.2	−1.6	8.8	−1.2	6.4	−0.8	0.5	−0.5	−5.9	−0.7
Seattle, Wash.[3] (10 m)	11	17.8	------	15.9	------	15.5	------	14.7	------	12.7	------	10.6	------	7.4	------	1.2	------	−5.9	------
Selfridge Field (Mount Clemens), Mich.[1] (177 m)	30	12.9	−1.1	14.3	−1.5	11.4	−2.4	8.6	−2.8	6.1	−2.9	3.9	−2.8	1.7	−2.5	−3.9	−2.7	−9.6	−2.5
Spokane, Wash.[2] (597 m)	29	11.1	+0.5	------	------	14.9	+0.1	12.6	−0.4	9.5	−0.2	5.9	−0.4	2.5	−0.7	−4.5	−1.3	−12.0	−2.3
Washington, D. C.[3] (13 m)	29	16.1	−3.1	16.3	−2.5	14.1	−2.9	12.0	−2.7	10.2	−2.1	7.9	−2.2	5.3	−2.5	0.6	−2.1	−4.6	−2.3
Wright Field (Dayton), Ohio [1] (244 m)	29	12.0	−2.2	16.0	−1.4	14.5	−1.9	11.9	−2.1	9.7	−1.9	7.1	−2.0	4.5	−1.9	−0.9	−1.5	−6.5	−1.2

[1] Army.
[2] Weather Bureau.
[3] Navy.

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month (years of record are given in parentheses following the number of observations): Barksdale Field, 86 (3); Billings, 108 (4); Cheyenne, 120 (4); Chicago, 90 (3); El Paso, 90 (3); Fargo, 116 (4); Kelly Field, 118 (4); Lakehurst, 66 (3); Maxwell Field, 113 (4); Mitchel Field, 97 (4); Nashville, 118 (4); Norfolk 146 (7); Oklahoma City, 116 (4); Omaha, 209 (7); Pearl Harbor, 140 (5); Pensacola, 220 (9); San Diego, 222 (9); Scott Field, 105 (4); Selfridge Field, 118 (4); Spokane, 113 (4); Washington, 218 (10); Wright Field, 112 (4).

TABLE 2.—*Mean free-air relative humidities (R. H.), in percent, and specific humidities (q), in grams/kilogram, obtained by airplanes during September 1937 (Dep. represents departure from "normal" relative humidity)*

Stations	Altitude (meters) m. s. l.																											
	Surface				500			1,000			1,500			2,000			2,500			3,000			4,000			5,000		
	Number of observations	q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.	
			Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.
Barksdale Field, La.	30	13.2	89	+3	10.6	58	−6	9.7	60	−6	8.4	58	−8	7.6	59	−5	6.9	59	−1	5.7	56	+1	4.1	55	+1	2.9	47	0
Billings, Mont.	20	5.7	55	−1							5.8	48	−1	5.0	49	+1	4.4	50	+1	3.7	51	+1	2.3	50	−3	1.4	43	−6
Boston, Mass.	28	8.2	85		7.2	66		6.7	68		5.6	62		4.8	55		3.6	44		3.2	42		2.3	38		1.2	29	
Cheyenne, Wyo.	30	6.5	66	0										6.9	59	−1	6.2	49	−1	5.2	48	0	3.8	53	+3	2.8	64	+11
Chicago, Ill.	30	7.7	76	−5	7.5	63	−4	6.6	64	+2	5.6	63	+5	4.4	52	0	3.7	47	−3	3.0	44	−3	2.4	48	−1	2.1	56	+9
Coco Solo, Canal Zone	27	18.3	95		16.3	85		14.5	84		12.6	81		11.2	80		9.5	77		8.2	74		6.8	82		4.9	79	
El Paso, Tex.	30	10.6	63	−2							9.6	51	−5	8.7	52	−5	7.9	56	−5	7.2	61	−1	5.3	67	+4	3.7	64	+8
Fargo, N. Dak.	29	6.7	78	−1	7.0	68	+1	6.4	62	−1	5.6	59	+2	5.0	57	+3	4.4	57	+5	3.7	57	+5	2.7	56	+6	1.8	55	+7
Kelly Field, Tex.	30	12.5	74	−15	12.5	67	−15	10.4	60	−14	9.0	59	−11	8.0	61	−7	6.8	59	−4	5.6	55	−3	4.4	59	+8	3.3	61	+11
Lakehurst, N. J.	26	8.6	93	+2	7.1	63	−5	6.0	60	−6	5.6	60	−2	4.4	49	−7	3.6	48	−5	2.9	43	−5	1.7	37	−3			
Maxwell Field, Ala.	27	12.6	83	−6	11.0	70	+2	9.2	64	−2	7.9	59	−5	6.6	54	−2	5.6	54	+2	4.8	50	+2	3.3	43	−3	2.0	35	−5
Mitchel Field, N. Y.	24	8.8	90	−1	8.3	76	−1	7.8	76	+2	6.9	72	+3	5.4	58	−5	4.5	52	−5	3.9	51	−3	2.6	46	−2			
Nashville, Tenn.	29	10.2	84	−2	10.0	70	+2	9.2	69	+1	8.0	67	−1	6.3	56	−5	5.2	51	−5	4.4	48	−4	2.9	42	−4	1.8	36	−3
Norfolk, Va.	24	11.3	84	+4	9.7	71	+1	8.1	69	+2	6.8	61	−2	5.4	52	−7	4.4	45	−9	3.5	40	−9	2.7	38	−7	1.7	33	−9
Oakland, Calif.	30	8.7	85		9.0	70		6.9	44		5.1	35		4.0	30		3.2	28		2.9	27		2.0	27		1.4	28	
Oklahoma City, Okla.	30	11.0	77	−3	10.7	68	−5	9.5	54	−8	8.6	54	−6	7.6	54	−4	6.9	56	0	6.1	59	+4	4.2	57	+5	2.9	55	+6
Omaha, Nebr.	29	8.6	73	−9	8.6	64	−7	7.7	56	0	6.8	54	+2	5.9	51	+1	5.0	49	0	4.2	49	+1	3.3	53	+6	2.2	49	+6
Pearl Harbor, Hawaii	30	14.2	84	+4	12.9	75	−2	12.1	81	+1	10.3	77	+1	8.4	71	+1	6.2	53	0	4.7	42	0	2.3	24	−7	1.3	19	−2
Pensacola, Fla.	28	14.2	93	+7	12.8	75	−3	11.1	72	−3	9.3	67	−3	8.1	67	0	6.7	60	−2	5.4	52	−5	3.6	44	−8	2.5	39	−9
St. Thomas, Virgin Islands	30	19.2	75		18.9	91		15.6	86		12.7	78		10.8	72		8.9	66		7.2	60		4.5	48		3.0	39	
Salt Lake City, Utah	30	6.3	53								7.2	44		5.9	38		5.0	38		4.5	41		3.6	48		2.9	57	
San Diego, Calif.	29	11.4	85	+6	10.8	76	−3	8.8	48	−6	7.1	38	−4	6.0	35	+2	5.4	36	+5	5.0	39	+9	3.7	41	+11	2.5	39	+14
Sault Ste. Marie, Mich.	30	7.3	87		6.6	72		5.8	69		5.2	68		4.4	64		3.8	61		3.4	61		2.3	56		1.4	47	
Scott Field, Ill.	27	8.1	82	−5	7.7	59	−2	7.4	60	+1	6.2	56	−1	5.0	49	−4	4.3	46	−6	3.7	44	−4	2.8	44	−2	2.1	49	+5
Seattle, Wash.	11	9.2	73		8.7	74		8.0	66		6.9	56		5.7	50		4.6	44		3.7	41		2.3	34		1.4	34	
Selfridge Field, Mich.	30	7.8	83	−3	6.8	64	−5	6.0	64	0	5.3	64	+2	4.6	61	+3	3.8	57	+4	3.2	52	+2	2.1	46	+1	1.4	43	+2
Spokane, Wash.	29	6.8	78	+7				6.3	53	+2	5.3	50	+2	4.7	51	+1	4.2	54	0	3.5	53	0	2.1	47	−1	1.4	48	+2
Washington, D. C.	29	9.5	84	+5	8.5	70	+4	7.3	66	+4	6.4	63	+2	5.4	56	−2	4.7	53	0	4.0	51	+1	3.0	47	+1	2.1	44	+7
Wright Field, Ohio.	29	7.9	89	−1	8.0	67	−3	7.2	63	−1	6.4	62	−2	5.0	54	−4	4.7	57	+3	4.2	57	+5	2.8	48	+1	2.0	45	+2

TABLE 3.—*Mean free-air barometric pressures (P), in mb, and equivalent potential temperatures (θ_e), in °A, obtained by airplanes during September 1937*

Stations	Altitude (meters) m. s. l.																											
	Surface			500		1,000		1,500		2,000		2,500		3,000		4,000		5,000											
	Number of observations	P	θ_e	P	θ_e	P	θ_e	P	θ_e	P	θ_e	P	θ_e	P	θ_e	P	θ_e	P	θ_e										
Barksdale Field, La.	30	1,010	329	959	330	905	330	854	329	805	329	758	329	714	328	632	329	558	330										
Billings, Mont.	20	894	312					851	318	802	318	754	318	710	318	626	316	551	317										
Boston, Mass.	28	1,018	307	960	311	905	312	852	313	802	314	754	315	710	317	626	320	554	321										
Cheyenne, Wyo.	30	815	320							803	326	755	329	712	328	630	327	556	325										
Chicago, Ill.	30	996	309	959	314	905	313	853	313	803	313	754	314	710	314	626	317	552	321										
Coco Solo, Canal Zone	27	1,009	348	955	347	902	345	850	342	802	341	756	338	712	337	630	338	558	337										
El Paso, Tex.	30	883	335					852	337	804	337	758	337	714	335	632	333	559	332										
Fargo, N. Dak.	29	983	304	957	310	902	313	849	314	799	315	752	316	707	316	623	318	549	319										
Kelly Field, Tex.	30	994	331	961	335	907	333	855	332	807	330	760	329	716	328	633	329	560	330										
Lakehurst, N. J.	26	1,013	309	958	312	903	312	850	314	801	314	753	314	708	314	624	315												
Maxwell Field, Ala.	27	1,011	328	960	325	906	326	854	326	805	325	758	324	713	325	634	325	560	327										
Mitchel Field, N. Y.	24	1,015	310	960	314	904	316	851	317	802	318	754	317	710	319	628	319												
Nashville, Tenn.	29	996	318	960	324	905	325	853	324	804	323	757	323	712	323	630	324	556	324										
Norfolk, Va.	24	1,017	322	960	322	906	319	854	319	804	319	757	320	713	320	630	322	556	325										
Oakland, Calif.	30	1,014	310	957	319	903	322	851	320	802	320	755	319	712	320	629	321	556	323										
Oklahoma City, Okla.	30	971	326	959	328	905	330	854	331	805	330	759	331	714	330	632	328	558	328										
Omaha, Nebr.	29	982	315	959	319	904	322	853	322	804	322	756	322	712	322	629	323	555	324										
Pearl Harbor, Hawaii	30	1,015	334	960	336	906	335	855	333	806	330	759	328	716	327	635	326	562	328										
Pensacola, Fla.	28	1,016	332	960	335	906	333	855	331	806	329	759	328	715	328	633	328	559	329										
St. Thomas, Virgin Islands	30	1,014	356	959	356	906	349	854	343	806	341	759	338	716	336	634	333	561	335										
Salt Lake City, Utah	30	872	318					851	328	802	328	755	327	712	327	629	327	556	328										
San Diego, Calif.	29	1,012	323	956	326	903	330	852	330	804	330	757	330	713	330	632	330	559	330										
Sault Ste. Marie, Mich.	30	990	305	958	307	902	308	849	309	799	310	750	311	706	313	622	314	547	316										
Scott Field, Ill.	27	1,003	309	961	316	906	318	854	318	804	318	757	319	712	319	630	322	555	324										
Seattle, Wash.	11	1,018	315	960	317	904	320	852	322	803	322	756	322	712	321	630	321	556	321										
Selfridge Field, Mich.	30	996	308	959	310	904	310	851	311	801	311	753	312	708	314	624	315	549	318										
Spokane, Wash.	29	946	308			902	315	850	315	801	315	753	316	708	315	624	315	549	315										
Washington, D. C.	29	1,019	314	962	316	907	316	854	317	804	318	757	319	712	320	629	322	555	325										
Wright Field, Ohio.	29	989	308	960	315	905	317	852	317	803	316	755	318	711	320	627	320	553	323										

TABLE 4.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during September 1937*

[Wind from N=360°, E=90°, etc.]

Altitude (m) m. s. l.	Albuquerque, N. Mex. (1,554 m)		Atlanta, Ga. (309 m)		Billings, Mont. (1,088 m)		Boston, Mass. (15 m)		Cheyenne, Wyo. (1,873 m)		Chicago, Ill. (192 m)		Cincinnati, Ohio (153 m)		Detroit, Mich. (204 m)		Fargo, N. Dak. (283 m)		Houston, Tex. (21 m)		Key West, Fla. (11 m)		Medford, Oreg. (410 m)		Nashville, Tenn. (194 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	356	1.8	53	1.1	317	1.7	316	1.3	273	2.5	220	0.8	45	0.6	288	0.9	215	0.5	30	0.8	76	2.1	262	0.3	100	0.3
500	-----	-----	97	3.7	-----	-----	316	4.7	-----	-----	231	3.6	153	0.6	292	1.6	219	1.0	163	3.4	97	4.2	266	0.8	153	2.5
1,000	-----	-----	104	3.8	-----	-----	307	5.3	-----	-----	255	3.8	267	2.1	282	2.9	269	4.0	150	3.4	102	3.3	282	1.3	187	2.3
1,500	-----	-----	111	1.9	41	0.2	301	5.2	-----	-----	267	4.2	279	3.1	292	4.1	283	5.7	123	2.2	101	2.8	70	0.6	257	1.8
2,000	152	1.8	294	0.3	273	1.4	296	6.3	271	3.5	285	4.8	286	3.4	292	5.9	294	7.2	74	2.0	102	0.8	133	1.2	273	2.4
2,500	225	2.2	199	0.2	269	4.0	295	6.0	265	4.5	298	5.2	294	4.9	292	7.4	290	7.6	49	2.6	240	0.4	199	3.2	272	2.3
3,000	253	2.6	267	0.6	277	5.5	293	6.9	275	5.5	298	7.4	301	4.5	289	7.4	292	8.8	38	3.1	288	1.7	189	3.6	273	2.8
4,000	275	2.8	280	2.1	267	5.5	-----	-----	267	7.0	-----	-----	-----	-----	290	8.6	-----	-----	320	0.7	-----	-----	214	5.2	300	4.8
5,000	257	2.5	-----	-----	269	7.1	-----	-----	285	7.2	-----	-----	-----	-----	291	6.9	-----	-----	227	4.6	-----	-----	199	6.0	-----	-----

Altitude (m) m. s. l.	Newark, N. J. (14 m)		Oakland, Calif. (8 m)		Oklahoma City, Okla. (402 m)		Omaha, Nebr. (306 m)		Pearl Harbor, Hawaii [1] (68 m)		Pensacola, Fla.[1] (24 m)		St. Louis, Mo. (170 m)		Salt Lake City, Utah (1,294 m)		San Diego, Calif. (15 m)		Sault Ste. Marie, Mich. (198 m)		Seattle, Wash. (14 m)		Spokane, Wash. (603 m)		Washington, D. C. (10 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	346	1.1	257	0.4	146	1.7	150	1.4	28	2.3	22	3.6	117	0.5	159	4.0	342	1.1	48	0.5	141	0.7	120	1.5	316	1.1
500	323	3.3	257	1.6	166	3.9	180	4.5	70	5.5	54	3.2	176	2.9	-----	-----	344	2.4	247	1.5	89	0.5	-----	-----	313	2.5
1,000	320	2.9	312	1.1	211	7.0	222	6.4	78	6.6	335	1.5	224	2.1	-----	-----	341	1.4	273	4.7	155	0.4	191	0.9	302	3.1
1,500	299	4.5	167	0.4	236	5.4	252	6.4	83	5.5	356	1.3	289	2.5	161	5.4	29	0.7	281	6.4	81	0.2	251	1.0	296	3.5
2,000	286	5.5	187	0.7	252	4.1	274	5.4	87	4.6	351	2.9	305	3.6	180	5.4	142	2.5	283	7.9	330	1.6	247	1.8	300	3.8
2,500	305	7.1	192	2.2	262	3.9	289	5.1	87	4.5	343	3.0	301	4.0	193	4.4	146	4.3	291	8.9	303	2.0	251	2.9	290	4.9
3,000	292	8.0	196	2.0	263	3.5	301	6.3	78	4.1	336	3.2	304	4.1	217	4.0	159	4.8	-----	-----	6	1.8	252	3.8	286	6.7
4,000	301	7.9	76	0.2	324	1.2	302	8.4	83	4.1	272	2.1	299	7.1	252	4.4	173	5.2	-----	-----	-----	-----	253	7.6	284	5.3
5,000	283	9.9	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

[1] Navy stations.

TABLE 5.—*Maximum free air wind velocities meters per second, for different sections of the United States based on pilot balloon observations during September 1937*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m) M. S. L.	Date	Station
Northeast [1]	37.0	NW	1,720	20	Newark	31.8	W	4,860	14	Albany	40.8	WNW	7,720	7	Cleveland.
East-Central [2]	27.8	WSW	570	18	Cincinnati	25.6	WSW	4,240	18	Washington	43.2	SSW	11,160	28	Greensboro.
Southeast [3]	22.8	ENE	670	29	Tampa	18.0	WSW	4,120	26	Spartanburg	33.2	SW	9,840	28	Charleston.
North-Central [4]	31.2	W	2,270	18	Detroit	32.2	NNW	4,970	19	Detroit	34.8	NW	7,670	5	Sault Ste. Marie.
Central [5]	32.7	SSW	1,480	23	Omaha	35.0	WNW	4,150	16	Omaha	42.0	W	10,840	6	Omaha.
South-Central [6]	26.2	NNW	2,500	16	Memphis	26.4	NNW	2,510	16	Memphis	36.2	W	9,350	11	Memphis.
Northwest [7]	20.6	SW	2,500	30	Medford	36.2	SW	3,200	30	Medford	47.0	NE	9,290	1	Portland.
West-Central [8]	28.0	WSW	2,500	22	Winnemucca	32.4	WSW	3,760	22	Winnemucca	50.0	WSW	11,560	7	Rock Springs.
Southwest [9]	20.7	SW	1,370	19	Las Vegas	33.1	SSW	3,360	20	Las Vegas	32.6	W	8,780	24	Winslow.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, northern Nevada, and northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in Charge]

By BENNETT SWENSON

During September 1937 moderate floods occurred principally in the rivers of eastern North Carolina and South Carolina, in the Apalachicola and Choctawhatchee Rivers in Alabama and Florida, and in the North Canadian River in Oklahoma. A tabulation of the crest stages appears below.

The floods in North and South Carolina were mainly a continuation of high water during the close of August with a second rise occurring during the second week of September as a result of additional rains. The losses from these floods were as follows: Roanoke River, $47,500; Neuse River, $2,550; and Tar River, $1,650. No damage of consequence occurred in the Saluda and Santee Rivers.

Heavy to excessive rains occurred over the Choctawhatchee and Apalachicola River watersheds on August 31–September 1, 1937, in connection with the passage of a slight tropical disturbance. Precipitation amounts for the 24 hours ending 7 a. m. September 1 for a few selected points in these watersheds were as follows: Newton, Ala., 10.86 inches; Geneva, Ala., 5.52 inches; Elba, Ala., 5.04 inches; Brundidge, Ala., 7.10 inches; Clayton, Ala., 3.02 inches; Troy, Ala., 7.46 inches; Brantley, Ala., 3.16 inches; Greenville, Ala., 2.14 inches; Caryville, Fla., 7.64 inches; and Blountstown, Fla., 4.12 inches.

These rains resulted in a light flood in the Apalachicola River and a moderate flood in the Choctawhatchee River from September 1–10. A total loss of about $62,500 was reported for the Choctawhatchee River while no damage of consequence occurred in the Apalachicola River.

Heavy rains over the upper watershed of the North Canadian River, from September 5–10, resulted in minor flooding in that river. The only material damage that occurred was in Harper County with a total of about $5,500.

An overflow occurred in the Ninnescah River in Kansas on September 8, caused by a heavy rain near Kingman, Kans., on the night of the 7–8th, totaling 5.35 inches. The loss resulting from this flood was estimated at $20,500.

Table of flood stages during September 1937

[All dates in September unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
James: Columbia, Va.	10	1	2	10.6	2
Roanoke:					
Randolph, Va.	21	1	2	21.3	2
Weldon, N. C.	31	1	3	32.9	2
		7	9	37.8	8
Scotland Neck, N. C.	23	[1] Aug. 25	[1] 1	28.9	Aug. 30
		[1] 8	[1] 11	27.5	10
Williamston, N. C.	10	Aug. 30	17	11.6	3
Tar:					
Rocky Mount, N. C.	8	Aug. 26	1	11.1	Aug. 27, 29, 30
Tarboro, N. C.	18	Aug. 30	4	21.9	1
Greenville, N. C.	13	Aug. 31	6	16.2	3
Neuse:					
Smithfield, N. C.	13	Aug. 25	2	18.1	Aug. 29
		7	10	14.5	8, 9
Goldsboro, N. C.	14	Aug. 29	7	18.6	3
Kinston, N. C.	14	2	9	16.1	6
Saluda:					
Pelzer, S. C.	6	7	9	7.4	8
Chappells, S. C.	15	10	10	15.3	10
Santee:					
Rimini, S. C.	12	Aug. 27	19	13.4	3
				13.6	12
		23	26	12.6	24
Ferguson, S. C.	12	Aug. 29	[2] 26	12.9	6
				13.1	14, 15
EAST GULF OF MEXICO DRAINAGE					
Apalachicola: Blountstown, Fla.	15	2	4	15.6	2, 3
Choctawhatchee:					
Newton, Ala.	19	1	3	26.3	2
Geneva, Ala.	23	2	6	31.6	3
Caryville, Fla.	12	2	10	15.6	4
MISSISSIPPI SYSTEM					
Ohio Basin					
West Fork of White: Anderson, Ind.	8	5	8	9.7	6
Arkansas Basin					
North Canadian:					
Woodward, Okla.	5	9	9	5.0	9
Canton, Okla.	6	9	10	6.3	10
Yukon, Okla.	8	8	18	11.3	11
		22	22	8.1	22

[1] Estimated. [2] Fell 0.2 foot below flood stage on 22d.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, WILLIS E. HURD, acting in charge]

NORTH ATLANTIC OCEAN, SEPTEMBER 1937

By H. C. HUNTER

Atmospheric pressure.—The average pressure of the month was slightly above normal over the southeastern portion of the North Atlantic; also the station at Belle Isle, Newfoundland, indicated an average excess of 0.06 inch. More noteworthy, however, were the regions of deficient pressure. The northeastern and north-central areas had decided deficiencies, the greatest noted being 0.18 inch at Reykjavik, Iceland; while near the American coast and the West Indies there was nearly everywhere a deficiency from the Gulf of St. Lawrence southward. At Bermuda the pressure averaged 0.08 inch less than normal.

The extremes of pressure noted in vessel reports are 30.62 and 28.20 inches. The higher reading was reported by radio on the evening of the 28th by the American liner *Scanpenn*, then about 100 miles east of Cape Race, where the meteorological station reported the same reading. Pressures almost as high had been reported by the American steamships *Topa Topa* and *Washington* on the 12th and 13th, respectively, near 47° N., 35° W. The lowest reading was noted by Norwegian motorship *California Express*, heavily involved in the northward-moving hurricane, about 1 a. m., on the 15th, near 20° N., 58° W.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, September 1937*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.67	−0.09	30.02	9	29.18	28
Reykjavik, Iceland	29.54	−.18	30.39	10	28.67	6
Lerwick, Shetland Islands	29.69	−.15	30.24	11	29.12	15
Valencia, Ireland	29.92	−.07	30.45	11	28.85	16
Lisbon, Portugal	30.05	+.03	30.18	22	29.83	17
Madeira	30.03	+.01	30.19	15	29.82	30
Horta, Azores	30.20	+.03	30.30	20, 23, 24	30.00	29
Belle Isle, Newfoundland	29.95	+.06	30.60	29	29.20	21
Halifax, Nova Scotia	30.02	−.03	30.52	28	29.10	26
Nantucket	30.03	−.05	30.40	30	29.41	11
Hatteras	30.05	−.01	30.38	30	29.72	13
Bermuda	30.00	−.06	30.18	5	29.76	25
Turks Island	29.93	−.05	30.03	7	29.84	24
Key West	29.92	−.02	30.06	7	29.77	13
New Orleans	29.99	+.01	30.23	29	29.77	19

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—There was considerably more storminess than in the summer months. One storm which seems to have originated outside the Tropics deserves special mention. On the evening of the 9th a moderate cyclonic circulation was indicated to the southwestward of Bermuda. The center traveled first toward the north-northwest, then northward till by the morning of the 11th it was a well developed LOW near the 70th meridian in the latitude of Cape May, N. J. After gaining in intensity and in speed of advance, while moving slightly to the east of north, the center was over the northwestern part of the Gulf of St. Lawrence on the morning of the 12th, whence it continued rapidly northward. During the 11th and 12th a steam yacht was grounded near Yarmouth, Nova Scotia, and a trawler on Sable Island, but no loss of life seems to have occurred.

From the 14th to 16th an intense LOW, probably a continuation of that previously described, though now traveling to southeastward, moved from Iceland to the British Isles. On the 14–15th the Danish steamship *Tennessee*, west of the path of the LOW, near 57° N., 24° W., met force-11 winds. This encounter in high latitude and the almost simultaneous meeting of like force to southward of the Tropic of Cancer by the Norwegian motorship *California Express*, mentioned in the synopsis of tropical disturbances, were apparently the first occurrences of force exceeding 10 over any part of the North Atlantic since mid-April. Chart IX, for the 16th, shows this northern storm centered near the British Isles.

Tropical disturbances.—Elsewhere is a synopsis of six disturbances which started within the Tropics. The greatest wind force attained in connection with any of these was force 12, on the 18th and 19th, met by three steamships. The second storm, which passed far to the eastward of Bermuda, was the one causing the hurricane winds mentioned. It is an earlier phase, on the 16th, of this LOW that is shown on chart IX. The same chart includes the third depression, which was of shorter path and less strength; it may be noted over the southwestern part of the Gulf of Mexico.

Chart X, for the 24th, shows the fourth disturbance, which was then centered some distance to the east-southeastward of Bermuda. Its advance thereafter was toward the north-northwest, to reach Nova Scotia on the 26th. During the preceding night the Canadian tanker *Victolite*, about 200 miles to southward of Halifax, encountered force-11 winds in connection with this LOW.

Figure 1 indicates the tracks of all six of these tropical disturbances of the month.

Fog.—The amount of fog from the shores of New Jersey, Long Island, and southern New England northeastward to the Grand Banks and the vicinity of Newfoundland, was much less in September than in August, and the final fortnight of September, particularly, was a period of little or no fog in this area. However, the foggiest 5°-square of the entire North Atlantic region this month was in the Grand Banks section, namely, from 40° to 45° N., 45° to 50° W., where fog occurred on 11 days.

In midocean and to eastward the amount of fog was about the same as during August, some squares reporting more and others less. The week from September 5 to 11 was in general the foggiest part of the month to northward of the 45th parallel from the 35th meridian eastward.

Compared with the expected occurrence of fog in September the present month shows mainly less than usual in western sections; but between the 45th and 50th parallels of latitude from midocean to the coast of France, there generally was more fog than shown by averages of previous Septembers.

OCEAN GALES AND STORMS, SEPTEMBER 1937

Vessel	Voyage		Position at time of lowest barometer		Gale began September—	Time of lowest barometer September—	Gale ended September—	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Black Eagle, Am. S. S.	New York	Antwerp	47 39 N.	32 07 W.	1	Noon, 1	2	30.02	NW	NW, 7	WNW	NW, 8	
Scanmail, Am. S. S.	Copenhagen	New York	54 00 N.	36 12 W.	1	10p, 1	1	[1] 29.74	NW	NW, 8	NW	NW, 10	None.
Berlin, Ger. S. S.	Bremerhaven	do	52 09 N.	30 30 W.	5	Noon, 5	5	29.54	WSW	WSW, 8	NW	WSW, 8	WSW-NW.
Tulsa, Am. S. S.	Charleston	Liverpool	46 04 N.	39 40 W.	6	5p, 7	9	29.77	NE	S, 8	S	S, 8	ENE-S-SW
Mercier, Belg. S. S.	New York	Antwerp	49 39 N.	5 51 W.	9	8p, 9	9	30.00	W	NNE, 8	NNE	NNE, 8	W-NNE.
Leto, Du. S. S.	Rotterdam	Wabana	48 23 N.	46 55 W.	9	8p, 9	10	29.67	W	S, 7	NW	NW, 10	S-NW.
Winamac, Br. S. S.	Aruba	Gibraltar	21 30 N.	57 12 W.	9	10a, 10	11	29.39	NNE	NNE, 10	SE	NNE, 10	NNE-SSW.
Telamon, Du. S. S.	Amsterdam	Arecibo	24 21 N.	57 16 W.	10	6p, 10	11	29.68	ESE	ESE, 8	WSW	ESE, 8	None.
West Madaket, Am. S. S.	Mobile	London	38 04 N.	66 33 W.	10	4a, 11	11	29.71	ENE	SE, 8	SSW	SE, 8	E-S.
Coppename, Am. S. S.	Boston	Guantanamo	36 24 N.	70 51 W.	11	Noon, 11	11	29.19	E	W, 10	W	W, 10	SE-W.
Zarembo, Am. S. S.	New York	Tenerife	39 30 N.	67 18 W.	10	4p, 11	12	29.52	ESE	SSW, 10	SW	SSW, 10	SSE-SSW-SSE.
American Trader, Am. S. S.	do	London	40 20 N.	67 35 W.	11	9p, 11	11	29.11	SE	SSW, 10	SW	S, 10	SE-SW.
Spaarndam, Du. S. S.	Rotterdam	New York	41 37 N.	66 10 W.	11	10p, 11	12	29.33	SSE	SSE, 9	SW	SSE, 9	SSE-SW.
Cadillac, Br. S. S.	Newcastle	Baytown, Tex.	33 50 N.	63 20 W.	12	2a, 13	13	29.30	ENE	N, 9	W	N, 9	NE-N-W.
Laurent Meeus, Belg. M. S.	Houston	Amsterdam	38 55 N.	62 20 W.	13	2p, 13	14	29.91	ESE	SSE, 8	SSE	SSE, 9	ESE-SSE.
Cyrus Field, Br. S. S.	Vera Cruz	Halifax	42 50 N.	65 48 W.	14	5a, 14	14	29.30	ENE	NNW, 7	SSW	NE, 8	NE-NW.
Tennessee, Dan. S. S.	South Shields	New York	56 40 N.	24 17 W.	14	5p, 14	16	29.53	WNW	WNW	WNW	NW, 11	WNW-NW.
De Grasse, Fr. S. S.	Cobh	Boston	51 18 N.	11 00 W.	16	7a, 16	17	28.83	W	NW, 9	NW	NW, 9	None.
Bremen, Ger. S. S.	Cherbourg	New York	49 41 N.	11 14 W.	16	10, a, 16	17	28.93	NW	NW, 9	NNW	NW, 10	W-NW.
Europa, Ger. S. S.	New York	Cherbourg	49 08 N.	2 50 W.	16	8a, 17	17	[1] 29.00	NW	S, 6	SSE	NNW, 10	
City of Alma, Am. S. S.	Mobile	Liverpool	51 00 N.	15 45 W.	15	11a, 17	18	29.57	WNW	NNW, 4	NW	WNW, 9	None.
Motocarline, Pan. M. S.	Nyborg	Aruba	[2] 30 32 N.	46 29 W.	17	1a, 18	18	29.82	SE	S, 9	S	S, 9	S-SSW.
Otho, Am. S. S.	St. Vincent, C. V. I.	Boston	34 14 N.	50 02 W.	17	5a, 18	18	28.54	S	NNW, 12	W	ESE, 12	E-NNW-W.
Oropesa, Br. S. S.	La Pallice	Bermuda	[2] 35 27 N.	47 55 W.	18	9a, 18	18	29.53	SE	SE, 11	SSE	SE, 12	SE-SSE.
Maria, Ital. M. S.	Gibraltar	New York	37 38 N.	45 35 W.	18	Noon, 18	19	29.92	SSE	SSE, 6	SW	S, 9	SSE-SW.
Lubrafol, Belg. M. S.	London	Port Arthur	[2] 36 37 N.	46 43 W.	18	4p, 18	18	29.80	SE	S, 9	SW	S, 9	SSE-SW.
De Grasse, Fr. S. S.	Cobh	Boston	46 42 N.	40 24 W.	19	11a, 19	20	29.30	SSE	SSE, 10	WSW	SSE, 10	SSE-S.
Minnequa, Am. S. S.	Gdynia	Baltimore	52 20 N.	40 53 W.	20	1a, 20	20	29.14	W	N, 8	W	W, 8	NNE-NNW.
Scanstates, Am. S. S.	Copehagen	New York	56 16 N.	24 12 W.	20	3a, 21	21	28.83	S	S, 8	NW	NW, 9	S-NW.
Marigot, Fr. S. S.	Falmouth	Guadeloupe	[1] 22 24 N.	52 41 W.	21	2a, 22	22	[1] 29.19	SE	NW, 10	W	N, 10	NE-N-W.
San Antonio, Fr. S. S.	Curacao	Havre	[1] 28 03 N.	54 31 W.	22	8p, 23	24	29.30	NNE	NE, 9	SSW	ENE, 10	E N E- N N E-NW.
Black Hawk, Am. S. S.	Rotterdam	New York	51 17 N.	24 07 W.	26	8p, 25	26	29.60	W	W, 4	N	NW, 8	SW-W.
Ogontz, Am. S. S.	Galveston	Montreal	41 36 N.	66 19 W.	25	Mdt, 25	26	29.36	NE	NNW, 9	W	NNW, 9	N-W.
Victolite, Br. M. S.	Guiria	Halifax	[2] 42 24 N.	63 12 W.	25	2a, 26	26	28.71	NE	SE, 10	WSW	NE, 11	E-S.
Europa, Ger. S. S.	Cherbourg	New York	42 15 N.	59 54 W.	26	Noon, 26	26	[1] 29.60	S	SW, 10	SW	SSW, 10	SSW-SW.
El Almirante, Am. S. S.	New Orleans	do	24 24 N.	81 30 W.	29	7p, 27	30	29.88	NE	NE, 4	NE	NE, 8	E-NE.
Standard Arrow, Am. S. S.	Beaumont	Paulsboro	28 20 N.	79 43 W.	28	4p, 28	30	30.04	NE	NE, 6	NE	NE, 8	Steady.
S. B. Hunt, Am. S. S.	Port Arthur	Providence	24 36 N.	80 24 W.	29	6p, 28	29	29.95	NNE	NE, 6	NE	NNE, 8	
Seminole, Am. S. S.	Galveston	Miami	[2] 26 44 N.	87 30 W.	30	[3] 2a, 1	[3] 1	29.70	NNE	NE, 7	SE	NE, 8	NE-SE.
NORTH PACIFIC OCEAN													
President Jefferson, Am. S. S.	Yokohama	Victoria, B. C.	[2] 50 00 N.	166 23 W.	2	10p, 2	3	29.82	SSE	SSE, 8	SSE	SSE, 9	
President Jackson, Am. S. S.	Seattle	Yokohama	50 48 N.	174 55 W.	1	Mdt, 2	2	29.52	SE	SSW, 7	S	SSE, 10	S-SSW-W.
Kekoskee, Am. S. S.	Los Angeles	Balboa	18 15 N.	103 45 W.	9	4a, 9	9	29.76	E	ESE, 5	SE	E, 8	ESE-E.
Steel Engineer, Am. S. S.	Longview, Wash.	do	19 48 N.	106 00 W.	9	4a, 10	10	29.76	SE	SE, 9	ESE	SE, 9	None.
San Lucas, Am. S. S.	Balboa	San Diego	[2] 22 09 N.	109 05 W.	9	3p, 10	13	29.52	E	E, 7	SE	E, 10	
Bengal Maru, Jap. S. S.	Los Angeles	Balboa	24 12 N.	112 13 W.	11	2p, 11	11	29.74	E	SE, 8	SSE	ESE, 8	
Talthybius, Br. S. S.	Seattle	Yokohama	52 04 N.	144 08 W.	11	4a, 12	12	29.48	SSW	S, 7	SSW	S, 10	S-W.
San Pedro Maru, Jap. M. S.	Los Angeles	Kobe	38 12 N.	144 15 E.	12	8a, 12	12	29.49	SSE	S, 9	SW	S, 9	SSE-SSW.
Hikawa Maru, Jap. M. S.	Yokohama	Vancouver	50 05 N.	173 26 W.	13	8p, 14	16	28.87	SSE	SW, 8	SW	SE, 8	SSW-WSW.
Nankai Maru, Jap. M. S.	do	San Francisco	45 12 N.	178 24 E.	15	Mdt, 15	15	29.51	W	W, 8	W	W, 8	
Empress of Japan, Br. S. S.	Honolulu	Yokohama	34 21 N.	158 41 E.	16	4a, 16	16	29.86	ENE	ENE, 7	NE	NE, 8	N-ENE.
Delftdijk, Du. M. S.	Los Angeles	Cristobal	20 17 N.	107 13 W.	16	Mdt, 16	17	29.64	SE	S, 7	SSW	SSE, 7	SSE-S.
Taketoyo Maru, Jap. S. S.	Yokohama	Los Angeles	43 38 N.	162 25 E.	19	11p, 19	20	29.42		WSW, 9		WSW, 9	
Texas, Am. S. S.	Bugo, P. I.	San Francisco	38 24 N.	124 42 W.	20	4p, 20	20	29.99	NNE	NNW, 8	NNW	NNE, 8	NNE-NNW.

[1] Barometer uncorrected.
[2] Position approximate.
[3] October.

NORTH PACIFIC OCEAN, SEPTEMBER 1937

By WILLIS E. HURD

Atmospheric pressure.—Average pressure over the Aleutian Islands, including the eastern part of the Bering Sea and the Gulf of Alaska region, was above the normal of the month, except as indicated at Dutch Harbor, with an average of 29.73 inches, which was slightly below. The Aleutian cyclone, following its almost complete disappearance in August, was reestablished in September as a result of the increasing depth and frequency of the northern Pacific disturbances usual to early autumn.

The north Pacific anticyclone occupied on an average a great part of the east-central and the extreme northeastern part of the ocean, with pressures at most island and coast stations within its boundaries showing very small excesses above normal except at Juneau, where the departure was as much as +0.11 inch.

Average pressures in the Far East, as shown in the following table, were 0.10 inch higher than the normal at stations in the Nansei and Ogasawara Islands, and slightly higher over the island groups to the southward.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, September 1937, at selected stations*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	29.82	−0.08	30.38	29	29.20	16
Dutch Harbor	29.73	−.03	30.44	26	28.72	15
St. Paul	29.78	+.07	30.48	26, 28	28.82	15
Kodiak	29.81	+.10	30.44	27	28.96	10
Juneau	30.03	+.11	30.33	27	29.64	29
Tatoosh Island	30.06	+.06	30.51	24	29.48	30
San Francisco	29.94	.00	30.12	24	29.80	20
Mazatlan	29.85	+.03	29.92	23	29.74	17
Honolulu	30.02	+.02	30.11	1	29.91	26
Midway Island	30.02	+.01	30.18	7	29.84	26
Guam	29.86	+.03	29.92	8, 10	29.82	6
Manila	29.80	+.03	29.86	12, 13, 18, 19	29.62	10
Hong Kong	29.83	+.06	29.96	29	28.30	2
Naha	29.86	+.10	30.00	19, 20, 28, 29	29.32	9
Chichishima	29.96	+.10	30.18	3, 15	29.71	24

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh asland, San Francisco, and Honolulu, which are based on 2 observations. Departures Ire computed from best available normals related to time of observation.

Extratropical cyclones and gales.—Several cyclonic disturbances occurred in high latitudes of the north Pacific during September. Barometer readings below 29 inches were recorded at Kodiak on the 10th; on board the Japanese motorship *Hikawa Maru*, near latitude 50° N., longitude 173½° W., on the 14th; and at Dutch Harbor and other nearby points on the 15th. The highest local winds reported in the vicinity of the storm areas on these dates, however, did not exceed force 8. The strongest winds experienced by reporting ships in northern waters were of force 10. One was reported by the American steamer *President Jackson*, on the 2d, a short distance south of the central Aleutians; the other, by the British steamer *Talthybius* on the 12th, near 52° N., 144° W.; both were accompanied by barometric minima of about 29.50 inches.

Gales of forces 8 to 10 were local in connection with all high latitude disturbances, and, so far as indicated by ships' mail and radio observations, occurred in scattered localities on only 10 or 12 days.

Most of the cyclones were irregular in movement. One, however, can be traced from a position east of northern Japan on the 17th, until it entered Alaska on the 24th. It appeared to have little intensity; the only gales worthy of mention within its field occurred on the 19th, of force 9, to the southwestward of the western Aleutians.

The only gale reported in coastal waters of the United States was of force 8, from north-northeast, experienced by the American steamer *Texas*, near Point Arena, Calif., on the 20th.

On the 29th and 30th a storm area of moderate intensity lay off the coasts of Washington and British Columbia. In connection with it, a gale of force 8 was reported by radio north of Queen Charlotte Island on the 29th. Similar reports on the 30th showed that winds of like force were blowing at a considerable distance to the southward, one being as far south as 45½° N., 132° W.

Tropical cyclones—Typhoons.—A very mild disturbance west of Mexico appeared near 15° N., 102° W. on September 1 and, moving northwest, disappeared on the 3d near the Revillagigedo Islands. No high winds were reported in connection with this disturbance.

During the 9th to 11th a cyclone of considerable intensity moved from a location about west of Acapulco northwestward past the mouth of the Gulf of California, and disintegrated at some distance west of southern Lower California. The earliest gale in connection with the disturbance was from the east, force 8, barometer 29.76, met by the American steamer *Kekoskee*, near 18° N., 104° W., on the 9th. At 4 a. m. of the 10th, in 19°48′ N., 106° W., the American steamer *Steel Engineer* had a southeast gale of force 9, barometer 29.76. Later in the day, a short distance south of Cape San Lucas, the American steamer *San Lucas* encountered the strongest wind, from the east of force 10, and the lowest barometer, 29.52, observed in connection with the storm. The highest wind reported on the 11th was of force 8, from the east-southeast, experienced at 2 p. m. on the Japanese steamer *Bengal Maru*, in 24°12′ N., 112°13′ W.

Disturbed conditions lay over and in the vicinity of the Gulf of California on the 16th to 20th, but cyclonic development was immature. The highest wind reported during the period was of force 7, from south-southeast, near 20° N., 107° W., met by the Dutch steamer *Delftdyk* barometer 29.64.

In the Far East much more serious cyclonic storms occurred, in particular the intense typhoons that ravaged Hong Kong on September 2 and southern Japan on September 11. These and other tropical cyclones of the month are described elsewhere in this issue of the REVIEW by the Rev. Bernard F. Doucette, S. J., of the Manila Observatory, Philippine Weather Bureau. The only note that may be added in connection with the Japanese typhoon is that one of our observing vessels, the Japanese motorship *San Pedro Maru*, while near 38° N., 144° E., on the 12th, experienced a south gale of force 9, barometer 29.49, as the storm entered the open Pacific from northern Honshu.

Fog.—There was a considerable decrease in the September occurrence of fog over that of the preceding month along the northern steamer routes. Between the Aleutian Islands and Japan practically all the fog reported was observed, rather scattered, on the 5th to 9th. From northern midocean eastward to longitude 130° W., there were 12 days reported with fog, scattered along the route, and occurring on not more than 5 days in any one 5-degree square. No fog was reported by ships along the Washington and Oregon coasts, but along the California coast it occurred on at least 12 days, and off Lower California on 2 days. Fog was observed on the 2d southwest of the Revillagigedo Islands.

TYPHOONS AND DEPRESSIONS OVER THE FAR EAST, SEPTEMBER 1937

Rev. BERNARD F. DOUCETTE, S. J.

[Weather Bureau, Manila, P. I.]

Typhoon August 24–September 3, 1937.—From August 24 to 30, as this storm moved west-northwest across the Pacific from a position about 200 miles south of Guam, there was little evidence of its potentialities. During the afternoon of August 28, the U. S. S. *Ramapo* experienced a shifting of winds that indicated the passage of the center a short distance south of the ship's position. It is possible that for some hours the center did shift its course in that way, but the next day found it moving along a west-northwest course. The lowest barometer reading on board the U. S. S. *Ramapo* was 29.61 inches at 4 p. m. August 28 (Manila time). The wind was coming from the north-northwest, velocity 33 knots, the ship being near latitude 13°4′ N., longitude 131°7′ E. (the position

of the ship at 4:45 p. m. when the shift of the wind to the east occurred). If the depression had already developed into a typhoon at this stage, it was a very small center and the hurricane winds did not extend far away from the calm area. In the early hours of August 30, however, it began to intensify in earnest (about 400 miles east of Luzon), as it moved west-northwest toward the Balintang Channel. Passing about 30 miles south of Basco, August 31, it then inclined somewhat to the west, and shortly after took a west-by-north course, which brought the typhoon center close to and north of Pratas, and later, close to and south of Hong Kong. It disappeared into the Continent September 3.

From August 31 to September 2, this typhoon was very violent and inflicted very much damage in Hong Kong as it passed that locality. Basco, Batan Province, on August 31, 1 p. m. had its barometric minimum, 739.43 mm (29.102 inches, gravity correction applied). The wind was east-northeast, force 9 at the time. One hour before, the wind was from the same direction but with a force of 11, the most violent winds experienced at the station during the passage of the typhoon. From Pratas, September 1, 2 p. m., the observation received was, barometer 744.9 mm (29.327 inches) with northwest winds, force 8. Thus far the typhoon was intensifying quite rapidly, but its real strength was not manifested until it reached the locality of Hong Kong, during the early morning hours of September 2.

The official statement of Mr. C. W. Jeffries[1] submitted to the press after the typhoon had passed is given below.

The typhoon formed to the east of Luzon during August 28 to 30. Its position was indefinite until the afternoon of the latter date when it was situated about 300 miles northeast of Manila moving northwest-by-west. By the morning of August 31 it had reached the eastern extremity of Balintang Channel, from thence on moving in a westerly direction until 6 a. m. Wednesday (Sept. 1) when it was situated about 100 miles east-by-south of Pratas Shoal. From this period it moved west-northwest, passing to the north of Waglin and the south of the Royal Observatory between 3 and 4 a. m. yesterday (Sept. 2). The stand-by signal No. 1 was hoisted at 12:35 a. m. Wednesday and signal No. 5 denoting gale from the northwest at 3:20 p. m. The No. 10 signal denoting a wind of typhoon force was expected was hoisted at 1:58 a. m. and bombs fired at 2:10 a. m. yesterday.

The wind increased rapidly in force until 2 a. m. blowing from the north and veering toward east after 3:30 a. m. By this time the squalls were of a phenomenal intensity, many occurring which were beyond the capacity of the anemograph, that is, greater than 125 m. p. h. The lowest reading of the barometer was 28.30 inches between 3:45 and 3:50 a. m. The rainfall amounted to 5.055 inches between 10:30 a. m. on Wednesday and 7:30 a. m. yesterday (September 2). The typhoon afterward entered the coast and filled up to the northwest of Macao.

After passing Pratas on Wednesday, the storm gave no indication of the intensity which characterized its passage across the Colony. It is doubtful if a storm of greater severity and destructive power has ever visited the Colony. The barometric minimum of 28.298 inches compared with the previous record of 28.590 inches on August 18, 1923.

Shortly after dawn there were signs that the gale was decreasing in force, although a fierce wind continued to sweep the Colony, leaving destruction in its wake. At 7:20 a. m., the No. 8 signal (gale expected from southeast) was hoisted.

A complete account of the destruction wrought by this typhoon cannot be given here. A few details from Manila newspapers will be given to indicate the extent of the catastrophe. The loss of life was estimated to be at least 500. The property loss due to the rains and the tidal waves could not be estimated. Many ships were cast upon the shore, some seriously damaged. Of these ships, the Manila papers made prominent mention of the S. S. *Asama Maru*, the S. S. *Conte Verde*, and the S. S. *Van Heutz*. Later on, news that the *Conte Verde* had been refloated was received. Concerning the other ships, no special news has been given to the public.

Typhoon, August 31–September 13, 1937—Secondary depression, September 7–9, 1937.—As a depression during the first part of its course, this storm moved northwest and west-northwest from its region of formation about 150 miles south of Yap. When it reached the locality of latitude 17° N., longitude, 126° E., it recurved to the northeast, moving slowly along this course and gradually intensifying, so much so that a secondary depression formed, probably on September 7. On September 8, however, the primary disturbance really manifested the strength of a well-developed typhoon which then traveled rapidly toward the west, changing to this course during the forenoon of September 8. It again recurved to the northeast when about 60 miles south-southeast of Naha. Along this northeasterly course, it moved toward Japan, crossing the southern part of that country and entering the Sea of Japan. There it gradually inclined to the east-northeast, traversed northern Japan, and continued on toward the Aleutian Islands.

It might be of interest to place on record some of the observations received for the weather map which indicate the intensity of the storm. All of these observations were made on September 10, when the typhoon was located over the Nansei (Loochoo) Islands. At 6 a. m. Oshima had southeast wind, force 5 with pressure 745.0 millimeters (29.331 inches); Naha had northwest winds force 7 with pressure 744.6 millimeters (29.315 inches); and Borodino had south wind force 8 with pressure 745.0 millimeters (29.331 inches). The afternoon observations (2 p. m. Manila time) were as follows. Oshima reported northeast wind force 7 and pressure 735.1 millimeters (28.941 inches); Naha reported west-northwest wind, force 6, and pressure 747.1 millimeters (29.413 inches); and Borodino reported southeast wind force 7 and pressure 747.8 millimeters (29.441 inches).

As this typhoon crossed southern Japan, September 11, serious damage to property occurred, but the news dispatches did not give details except to state that most of the damage was along the coast and was inflicted upon small vessels.

From September 7 to 9, a secondary depression appeared about 300 miles east-northeast of Manila. It moved northward and on September 10 was absorbed into the more active disturbance over the Nansei (Loochoo) Islands.

Typhoon, September 14–22, 1937.—A depression originated about 120 miles southwest of Yap and moved along a west-northwest course to the northern part of central Luzon, which it crossed during the night of September 17. In the China Sea it inclined somewhat to the northwest for 1 day, and then took a westerly course, crossing Hainan Island. Here it intensified and entered Indo-China as a typhoon, but quickly diminished in intensity as it moved inland. No trace of it could be found on the weather maps of September 22. With the morning reports of September 21, Phulien included the statement that winds of force 11 were experienced at that station at 2 a. m. that morning. The direction was not stated, but was, most likely, from the northeast quadrant.

[1] The South China Morning Post, September 3, 1937, published in Hong Kong.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE I.—*Condensed climatological summary of temperature and precipitation by sections, September 1937*

[For description of tables and charts, see REVIEW, January, p. 29]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	73.7	−2.0	Robertsdale	97	9	Riverton	40	29	3.96	+0.44	Ozark	13.70	Seale	0.66
Arizona	75.4	+2.7	Quartzsite	116	10	Fort Valley	29	26	1.61	+.37	Grand Canyon	5.86	Wellton	.06
Arkansas	72.7	−1.7	Gravette	102	8	2 stations	34	27	4.27	+.86	Bentonville	15.18	Texarkana	.32
California	68.8	+1.2	Greenland Ranch	118	11	Boca	19	5	.04	−.40	Orleans	1.58	147 stations	.00
Colorado	61.0	+3.1	2 stations	100	1	Pearl	7	25	1.20	−.12	Telluride	3.25	Kassler	.06
Florida	78.5	−.9	Cedar Keys	101	8	Lake City	51	29	7.13	+.42	Davie	21.28	Tampa	1.05
Georgia	73.1	−2.4	2 stations	98	15	Gainesville	42	15	2.53	−1.16	Bainbridge	8.78	Hartwell	.35
Idaho	60.0	+3.1	Lapwai	104	11	3 stations	15	24	.58	−.46	Deception Creek	1.74	Glenns Ferry	T
Illinois	66.5	−.7	Fairfield	99	1	Dixon	28	27	2.31	−1.35	Urbana	5.34	Streator	.35
Indiana	64.9	−2.3	Shoals	103	2	Marengo	29	28	3.24	−.18	Winslow	7.25	Evans Landing	.77
Iowa	65.9	+2.1	Osceola	103	21	3 stations	28	16	1.50	−2.32	Sanborn	3.46	Audubon	.18
Kansas	71.3	+1.7	3 stations	106	3	Centralia	30	26	1.90	−.93	Emporia	7.81	Olathe	.07
Kentucky	67.8	−2.7	do	98	11	Farmers	29	18	1.84	−1.11	Burnside	4.71	Lockport	.48
Louisiana	77.2	−.8	Minden	103	20	Tallulah	36	28	3.56	−.33	Port Eads	11.11	Tallulah	.60
Maryland-Delaware	64.3	−3.6	2 stations	96	13	Oakland, Md	26	27	1.72	−1.45	Stevensville, Md	3.88	Aberdeen, Md	.70
Michigan	59.7	−.7	Five Channels Dam	96	3	Garnet	21	20	3.74	+.49	Wolverine	10.76	Milford	.97
Minnesota	60.0	+1.0	Wheaton	101	21	2 stations	23	19	2.02	−.83	Pokegama Falls	6.58	Crookston	.37
Mississippi	74.7	−1.2	Magnolia	99	21	Duck Hill	37	27	2.74	−.33	Durant	6.03	Crystal Springs	.39
Missouri	69.4	+.2	Grant City	103	3	Louisiana	29	17	2.41	−1.74	Hailey	12.37	Kansas City	.21
Montana	58.4	+3.6	Garland	101	19	Wisdom	15	30	1.50	+.14	Goldbutte	3.58	Superior	.22
Nebraska	67.3	+3.1	Pawnee City	104	3	Gordon	18	25	1.50	−.55	Watertown	6.51	Lebanon	T
Nevada	66.1	+5.0	Logandale	111	10	San Jacinto	16	24	.21	−.20	McGill	1.68	13 stations	.00
New England	60.0	−.3	Waterbury, Conn	98	1	5 stations	28	21	3.49	−.25	Williamstown, Mass.	8.19	East Ryegate, Vt	.92
New Jersey	63.4	−2.5	Elizabeth	98	2	Runyon	29	21	2.63	−.93	Sussex	4.41	Phillipsburg	.75
New Mexico	65.6	+1.1	Clovis	105	3	2 stations	18	26	2.23	+.58	White Tail	9.05	Vaughn	.10
New York	59.5	−1.8	Geneva	96	3	3 stations	25	18	2.66	−.75	Voorheesville	5.43	Dansville	.39
North Carolina	68.4	−2.6	Salisbury	96	5	Banners Elk	32	29	2.40	−1.60	Newbern	5.55	Swansboro	T
North Dakota	58.6	+2.0	Wishek	104	1	Linton	20	25	1.47	−.07	Powers Lake	3.93	Grand Forks	.46
Ohio	63.0	−2.6	Gallipolis (near)	99	2	Millport	28	18	2.45	−.53	Lima	6.03	Bangorville	.64
Oklahoma	74.6	+.2	Alva	105	3	Grove	35	26	3.15	−.03	Cherokee	10.71	Sulphur	.05
Oregon	59.3	+1.6	Oakridge	108	14	Chemuet	11	23	.79	−.40	Seaside	3.54	Halfway	.02
Pennsylvania	61.5	−2.7	Claysville	97	2	2 stations	25	18	1.90	−1.47	Mifflintown	5.72	Smethport	.55
South Carolina	71.8	−2.7	Estill	97	7	Long Creek (near)	42	30	3.08	−1.06	Georgetown	6.92	Winnsboro	.49
South Dakota	64.1	+2.7	Onida	106	1	2 stations	21	25	.97	−.53	Newell	2.87	Belvidere	.05
Tennessee	69.5	−2.0	Newbern	100	12	Crossville	31	28	2.68	−.39	Bolivar	6.11	Copperhill	.46
Texas	78.3	+1.0	3 stations	107	12	Muleshoe	39	22	2.04	−.85	Mexia	6.65	3 stations	.00
Utah	63.1	+2.5	St. George	102	12	Woodruff	14	25	1.15	+.15	Fruitland	3.44	Ibapah	.25
Virginia	64.9	−3.7	Lincoln	98	4	Mountain Lake	27	20	2.84	−.29	Diamond Springs	5.74	Wytheville	.76
Washington	60.4	+2.3	Wahluke (near)	99	12	Stockdill Ranch	23	24	1.27	−.55	Naselle	5.65	2 stations	.09
West Virginia	63.2	−3.2	2 stations	98	2	Bayard	23	18	2.18	−.73	Weston	4.95	Piedmont	.45
Wisconsin	60.7	+.4	Meadow Valley	101	2	Brule Island	21	27	2.99	−.65	Rest Lake	7.74	Plum Island	.38
Wyoming	57.8	+3.2	Rochelle	100	20	South Pass City	4	25	.81	−.32	Bechler River	2.68	2 stations	T
Alaska (August)	51.8	−1.3	Ruby	85	30	Council	24	6	4.32	+.86	Cordova	18.55	Kotzebue	.12
Hawaii	74.8	+.2	Hoaeae (upper)	94	28	Kanalohuluhulu	40	9	4.67	−1.33	Wahiawa Water Co.	21.65	4 stations	.00
Puerto Rico	79.3	+.5	Juana Diaz	99	8	Guineo Reservoir	57	24	6.45	−2.15	Toro Negro	20.54	Mona Island	.00

[1] Other dates also.

TABLE 2.—*Climatological data for Weather Bureau stations, September 1937*

[Compiled by Annie E. Small, by official authority, United States Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							60.9	+0.1										80	3.24	+0.1										4.5		
Eastport	76	67	85	29.94	30.02	−0.01	57.0	+1.2	87	4	64	43	9	50	32	53	50	84	4.41	+1.6	13	10.0	sw.	30	e.	11	10	10	10	5.7	0.0	0.0
Greenville, Maine	1,070	6	40	28.37	30.04	------	56.2	------	91	2	68	28	9	44	43	51	48	----	3.28	------	9	4.4	s.	19	------	15	10	10	10	------	.0	.0
Portland, Maine	103	82	117	29.92	30.04	−.01	61.0	+1.4	96	3	69	41	21	53	30	54	50	73	3.99	+.9	8	7.8	n.	21	sw.	14	19	5	6	3.4	.0	.0
Concord	289	60	----	29.74	30.04	−.02	59.8	+.5	93	3	71	36	22	48	39	----	----	----	2.66	−.8	9	------	ne.	------	------	----	17	7	6	------	.0	.0
Burlington	403	11	48	29.60	30.03	−.03	59.4	−.9	90	2	69	36	18	50	33	53	50	75	1.82	−1.7	8	8.1	s.	31	s.	15	9	11	10	5.5	.0	.0
Northfield	876	12	60	29.11	30.06	.00	56.0	−.1	89	3	68	32	18	44	40	51	49	86	1.33	−1.7	9	6.4	s.	24	sw.	15	9	8	13	6.0	.0	.0
Boston [1]	29	31	50	30.01	30.04	−.03	63.0	−.2	93	3	71	45	21	55	28	56	53	78	3.69	+.6	7	9.7	sw.	27	s.	19	15	8	7	4.0	.0	.0
Nantucket	12	14	90	30.02	30.03	−.05	63.4	+.6	81	4	70	49	30	57	19	59	57	85	4.27	+1.8	9	13.8	sw.	47	ne.	28	12	9	9	4.6	.0	.0
Block Island	26	11	46	30.02	30.05	−.03	62.9	−.5	79	3	68	51	30	58	18	59	57	83	3.54	+.9	8	13.7	sw.	38	ne.	28	16	5	9	4.7	.0	.0
Providence	159	215	251	29.88	30.06	−.01	62.9	−.3	92	4	72	44	21	54	26	56	53	78	3.01	−.2	8	9.8	nw.	43	nw.	4	15	10	5	3.5	.0	.0
Hartford	159	66	100	29.89	30.06	−.01	62.0	+.3	94	4	72	41	30	52	30	----	----	----	4.00	+.5	7	6.9	s.	24	nw.	20	17	7	6	3.9	.0	.0
New Haven	106	74	153	29.96	30.07	.00	62.8	−.7	92	4	72	42	21	54	25	57	53	74	2.90	−.6	6	8.2	n.	26	ne.	13	16	9	5	4.0	.0	.0
Middle Atlantic States							65.1	−1.9										75	2.40	−0.8									4.3		
Albany	97	97	112	29.96	30.06	−.01	61.6	−1.5	91	3	72	39	21	52	29	55	52	78	5.08	+2.0	10	6.2	s.	27	s.	15	13	9	8	4.7	.0	.0
Binghamton	871	57	79	29.16	30.10	+.03	60.3	−1.0	93	1	71	34	21	49	35	----	----	----	2.84	−.2	10	5.5	e.	28	sw.	3	10	11	9	5.4	.0	.0
New York	314	415	454	29.73	30.06	−.02	65.2	−1.6	89	2	73	45	18	58	27	58	53	71	4.04	+.6	6	11.9	n.	49	n.	13	17	7	6	3.9	.0	.0
Harrisburg	374	94	104	29.68	30.08	.00	63.8	−2.0	91	4	73	42	18	54	30	57	52	73	1.02	−2.0	6	6.0	w.	18	w.	19	15	10	5	4.1	.0	.0
Philadelphia	114	174	367	29.96	30.09	+.01	66.4	−1.6	91	1	75	46	18	58	25	59	54	69	1.55	−1.6	6	10.7	n.	27	s.	15	14	8	8	4.1	.0	.0
Reading	323	283	306	29.72	30.07	------	64.7	−1.6	92	4	74	44	18	56	27	57	52	69	.89	−2.3	5	8.6	nw.	30	w.	19	16	7	7	3.9	.0	.0
Scranton	805	72	104	29.22	30.08	+.01	61.2	−1.7	91	1	72	36	18	50	34	53	49	74	1.42	−1.8	7	5.4	n.	22	nw.	19	14	9	7	4.3	.0	.0
Atlantic City	52	37	172	30.01	30.06	−.01	65.8	−1.0	84	1	72	47	18	59	21	60	57	76	1.07	−1.6	4	13.9	w.	38	ne.	5	14	8	8	4.3	.0	.0
Sandy Hook	22	10	57	30.04	30.06	------	66.0	−1.5	91	2	72	50	18	60	21	59	56	75	3.71	+.3	6	12.9	sw.	52	n.	13	16	8	6	3.5	.0	.0
Trenton	190	88	106	29.86	30.07	------	64.3	−2.6	92	2	74	43	18	55	31	57	53	72	1.90	−1.5	6	7.4	s.	30	n.	13	14	8	8	4.5	.0	.0
Baltimore	123	100	215	29.95	30.08	.00	67.2	−1.3	96	4	76	47	20	58	28	59	54	68	1.10	−2.3	6	8.7	sw.	26	sw.	19	16	5	9	4.0	.0	.0
Washington	112	62	85	29.96	30.08	.00	65.9	−2.2	94	4	75	45	18	56	30	59	56	77	1.76	−1.5	7	5.4	nw.	18	nw.	19	16	6	8	3.9	.0	.0
Cape Henry	18	8	54	30.04	30.06	------	69.6	−2.2	93	4	76	53	21	64	26	64	61	77	3.94	+1.1	8	12.9	ne.	36	n.	28	16	6	8	4.5	.0	.0
Lynchburg	686	148	184	29.37	30.11	+.03	66.3	−2.7	94	4	77	43	18	55	35	59	57	81	2.61	−.7	5	5.2	nw.	28	nw.	5	15	8	7	4.0	.0	.0
Norfolk	91	80	125	29.98	30.08	+.02	69.9	−1.7	92	5	76	55	21	63	24	63	60	77	4.47	+1.2	8	8.7	ne.	29	nw.	5	10	13	7	5.1	.0	.0
Richmond	144	11	52	29.94	30.09	+.02	66.8	−3.7	91	4	77	45	18	57	31	60	58	81	2.61	−.6	7	6.5	ne.	19	nw.	5	16	6	8	4.1	.0	.0
Wytheville	2,304	49	55	------	30.11	+.04	61.8	−1.8	88	4	73	38	18	51	33	----	----	83	.76	−2.5	11	4.6	e.	20	w.	19	14	8	8	----	.0	.0
South Atlantic States							72.6	−0.7										80	2.98	−1.2									5.1		
Asheville	2,253	89	104	27.77	30.08	+.01	65.8	+.8	87	5	76	45	30	55	33	58	56	83	.67	−2.4	6	6.4	s.	20	se.	27	13	10	7	4.9	.0	.0
Charlotte	779	63	86	29.25	30.08	+.01	69.6	−1.9	91	5	79	48	27	60	29	62	58	75	2.31	−.7	6	6.6	ne.	17	ne.	30	11	10	9	4.7	.0	.0
Greensboro [1]	886	6	56	29.14	30.10	------	66.3	------	90	4	76	46	25	56	36	60	58	87	2.43	−.8	6	6.8	ne.	22	ne.	27	10	10	10	4.9	.0	.0
Hatteras	11	5	50	30.03	30.05	−.01	73.2	−1.3	86	6	78	62	19	69	14	68	66	79	3.13	−1.5	8	12.1	ne.	28	n.	28	13	8	9	4.8	.0	.0
Raleigh	376	103	140	29.66	30.06	−.01	69.5	−1.6	93	5	78	51	28	61	28	62	59	76	1.85	−1.8	3	7.8	ne.	19	ne.	26	14	9	7	4.2	.0	.0
Wilmington	72	73	107	29.98	30.05	.00	72.8	−.3	91	7	81	56	30	64	24	66	64	82	2.13	−2.4	8	7.7	ne.	19	sw.	15	12	11	7	4.8	.0	.0
Charleston	48	11	92	29.98	30.04	.00	75.5	−1.1	89	7	82	59	28	69	22	69	67	79	4.34	−.2	10	9.5	ne.	28	e.	22	8	12	10	6.0	.0	.0
Columbia, S. C	347	70	91	29.69	30.06	+.01	72.9	−1.6	92	7	82	52	28	63	29	64	60	73	1.27	−2.2	4	7.6	ne.	20	ne.	30	15	8	7	4.3	.0	.0
Greenville, S. C	1,039	139	----	----	----	----	70.3	−.3	90	7	79	50	28	62	24	----	----	----	4.19	+.5	7	------	ne.	------	------	----	16	7	7	------	.0	.0
Augusta	182	62	77	29.84	30.03	−.02	74.0	−1.3	92	6	84	54	28	64	29	66	63	76	.89	−2.5	2	5.5	ne.	16	se.	2	12	8	10	5.1	.0	.0
Savannah	65	73	152	29.95	30.02	−.01	76.8	+.6	94	7	85	58	28	69	22	69	67	82	4.73	−.7	14	8.7	n.	26	e.	22	8	12	10	6.1	.0	.0
Jacksonville	43	86	110	29.96	30.00	.00	78.1	−.2	94	8	85	64	28	71	20	71	70	82	7.87	+.5	14	7.4	ne.	24	n.	30	6	12	12	6.4	.0	.0
Florida Peninsula							80.8	+0.3										80	8.17	+1.1									5.9		
Key West	22	10	64	29.90	29.92	−.02	82.2	.0	92	20	88	71	28	77	18	76	74	81	8.01	+1.3	13	8.8	e.	34	w.	13	11	11	8	5.1	.0	.0
Miami	25	124	168	29.92	29.95	−.02	80.7	+.6	91	9	86	69	24	76	15	75	73	79	16.99	+8.6	15	8.7	se.	29	e.	24	5	13	12	6.1	.0	.0
Tampa	35	88	197	29.93	29.96	−.01	80.6	+.7	94	7	88	69	28	73	19	73	71	81	1.05	−5.4	8	10.1	ne.	32	e.	23	3	16	11	6.5	.0	.0
Titusville	43	5	36	29.92	29.97	------	79.6	−.2	95	7	89	64	17	70	28	73	72	----	6.62	−.2	17	------	ne.	------	------	----	4	15	11	----	.0	.0
East Gulf States							75.0	−0.9										77	4.10	−0.1									5.0		
Atlanta [1]	976	5	53	29.03	30.03	−.02	71.2	−1.2	93	7	81	51	29	61	31	63	60	78	.95	−2.0	3	6.6	ne.	22	nw.	4	11	10	9	5.0	.0	.0
Macon	370	79	87	29.65	30.04	+.01	73.2	−1.6	93	7	83	52	29	64	31	65	61	73	.53	−2.7	7	6.2	e.	18	e.	22	11	7	12	5.4	.0	.0
Thomasville	273	49	58	----	----	----	75.6	−1.2	92	3	84	56	29	67	24	----	----	----	5.56	+.7	8	------	------	------	------	----	----	----	----	------	------	------
Apalachicola	35	11	----	29.95	29.99	------	77.3	−1.2	92	9	84	61	29	71	20	71	69	81	5.87	−2.2	10	8.2	ne.	30	s.	20	11	7	12	5.5	.0	.0
Pensacola	56	149	185	29.95	30.01	+.02	76.1	−1.9	92	9	82	59	28	70	21	70	67	79	13.05	+7.7	12	11.3	ne.	41	e.	9	12	7	11	4.9	.0	.0
Anniston	741	9	----	----	----	----	71.2	−.1	88	8	80	48	27	62	29	----	----	----	.75	−2.9	10	------	s.	------	------	----	17	7	6	------	.0	.0
Birmingham	700	11	48	29.28	30.03	.00	73.3	−1.5	89	8	83	50	27	63	29	64	61	76	2.81	−.6	7	6.0	e.	20	se.	1	14	8	8	4.3	.0	.0
Mobile	57	86	161	29.94	30.00	.00	76.7	−1.4	93	9	85	54	28	69	24	69	67	79	3.16	−1.8	10	8.6	n.	26	nw.	11	10	6	14	5.5	.0	.0
Montgomery	218	92	105	29.79	30.03	+.01	74.8	−1.5	91	4	84	54	28	66	25	67	64	76	7.20	+4.2	7	6.3	ne.	20	sw.	6	12	8	10	5.2	.0	.0
Meridian	378	67	92	29.63	30.02	.00	74.7	+.2	93	9	85	46	28	64	33	66	63	77	1.76	−1.2	8	5.1	ne.	18	sw.	4	13	7	10	4.4	.0	.0
Vicksburg	247	82	102	29.75	30.01	−.01	76.1	−.2	92	21	86	48	27	67	28	67	63	72	1.27	−1.6	5	7.6	e.	20	se.	3	12	11	7	4.5	.0	.0
New Orleans	53	76	84	29.94	29.99	+.01	79.6	+.4	94	10	87	60	28	72	21	71	68	75	6.24	+1.2	14	6.6	ne.	19	e.	18	11	9	10	5.0	.0	.0
Port Eads, La	9	4	35	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
West Gulf States							79.0	+1.2										70	3.01	−0.7									3.8		
Shreveport	249	92	227	29.74	30.01	+.01	77.9	+1.0	100	20	88	52	27	68	30	68	63	69	3.34	+.5	7	8.7	ne.	28	ne.	1	15	11	4	3.8	.0	.0
Bentonville	1,303	12	38	28.67	30.02	.00	70.0	+1.1	92	4	80	40	26	60	30	----	----	----	15.18	+11.5	12	5.5	s.	15	sw.	18	13	8	9	----	.0	.0
Fort Smith	457	79	94	29.56	30.03	+.02	74.6	+.6	96	2	84	45	27	65	28	65	61	72	6.02	+3.0	14	6.9	e.	24	n.	25	14	6	10	4.8	.0	.0
Little Rock	357	94	102	29.66	30.03	.00	73.5	−.6	92	22	82	49	28	65	26	65	61	73	5.75	+2.6	8	6.9	e.	19	sw.	9	14	8	8	4.3	.0	.0
Austin	605	68	90	29.35	29.98	------	80.1	+1.8	97	1	91	55	28	69	33	68	62	62	2.21	−1.2	2	5.9	s.	20	n.	25	17	10	3	3.0	.0	.0
Brownsville	57	88	96	29.87	29.93	------	81.5	+.9	94	11	90	66	28	73	24	73	71	78	1.60	−3.9	5	9.0	se.	24	se.	8	14	12	4	4.4	.0	.0
Corpus Christi	20	11	78	29.94	29.96	+.01	82.4	+2.7	93	2	89	68	30	76	19	73	70	73	.57	−3.9	7	9.9	e.	28	ne.	17	18	6	6	3.3	.0	.0
Dallas	512	220	227	29.45	29.99	------	78.1	------	98	20	88	53	27	68	30	66	59	60	1.86	−.9	3	9.7	s.	40	sw.	2	16	10	4	3.7	.0	.0
Fort Worth	679	92	110	29.30	30.01	+.02	79.8	+2.9	100	20	91	54	26	69	30	----	----	----	.32	−2.2	4	8.3	s.	27	se.	3	18	10	2	2.9	.0	.0
Galveston	54	106	114	29.93	29.99	+.01	80.6	+.5	94	11	86	65	26	76	19	73	70	72	6.10	+.5	11	8.5	s.	22	w.	11	21	4	5	2.8	.0	.0
Houston	138	292	314	29.85	29.99	------	79.2	+.2	96	1	88	57	27	70	25	----	----	----	4.69	+.6	7	9.5	s.	22	nw.	3	13	8	9	4.7	.0	.0
Palestine	510	64	72	29.49	30.01	+.02	77.6	+.6	98	20	88	53	27	68	29	67	62	67	3.07	+.2	5	5.7	s.	17	s.	4	15	7	8	4.0	.0	.0
Port Arthur	34	98	106	29.95	29.99	------	78.9	------	93	1	86	67	27	71	23	70	67	74	3.56	−1.2	10	8.5	ne.	25	e.	17	13	11	6	4.3	.0	.0
San Antonio	693	242	301	29.26	29.96	.00	82.0	+3.0	100	11	92	62	28	72	28	69	63	60	.04	−3.0	2	9.4	e.	30	ne.	11	14	12	4	3.9	.0	.0

See footnotes at end of table.

TABLE 2.—*Climatological data for Weather Bureau stations, September 1937*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max.+mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01 inch or more	Wind: Average hourly velocity	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							67.1	−1.6										71	2.09	−0.9											4.0		
Chattanooga	762	71	214	29.25	30.05	−0.01	72.2	.0	91	3	82	48	28	62	32	63	60	73	2.30	−.8	9	5.6	se.	27	w.	5	15	10	5	3.8	0.0	0.0
Knoxville	995	66	84	29.02	30.06	.00	71.0	+.4	91	2	81	48	29	61	31	63	60	79	2.11	−.6	7	4.9	ne.	21	w.	5	18	5	7	3.6	.0	.0
Memphis	399	78	86	29.61	30.03	.00	72.8	−.8	91	22	81	48	28	65	28	64	60	70	2.50	−.3	6	6.6	e.	18	n.	25	16	3	11	4.7	.0	.0
Nashville	546	168	188	29.49	30.07	+.01	70.0	−1.8	91	1	80	43	28	60	33	61	57	70	2.05	−1.4	8	7.5	n.	22	n.	26	14	7	9	4.1	.0	.0
Lexington	989	6	.....	.....	.....	.....	67.5	−1.0	97	2	82	38	28	53	43	.....	.....	.....	.87	−2.2	6	.....	n.	.....	.....	.....	15	11	4	.....	.0	.0
Louisville	525	188	234	29.51	30.09	+.03	67.9	−2.6	92	1	78	43	27	57	37	58	53	66	1.09	−1.7	5	8.9	n.	25	nw.	25	18	7	5	3.4	.0	.0
Evansville	431	76	116	29.60	30.06	.00	69.6	−1.1	96	1	80	45	27	59	32	59	54	63	1.80	−1.5	4	7.7	s.	26	sw.	10	19	3	8	3.5	.0	.0
Indianapolis	822	194	230	29.21	30.09	+.03	65.4	−1.5	91	3	75	40	28	56	29	56	50	64	3.28	−.1	6	9.6	s.	29	s.	10	14	11	5	4.3	.0	.0
Terre Haute	575	63	149	29.45	30.06	.....	67.4	.....	97	1	79	40	27	56	35	57	52	66	1.63	−2.0	6	8.8	ne.	25	nw.	10	17	8	5	3.3	.0	.0
Cincinnati	627	11	51	29.41	30.09	+.02	65.4	−1.7	93	2	77	40	28	54	38	57	52	74	2.08	−.6	4	5.9	ne.	18	w.	15	16	10	4	3.9	.0	.0
Columbus	822	90	210	29.22	30.09	+.02	65.0	−1.5	91	3	76	41	27	54	36	56	50	66	2.45	−.1	7	7.6	n.	28	sw.	15	17	7	6	3.4	.0	.0
Dayton	899	60	163	29.13	30.08	.....	64.8	−1.8	92	2	75	41	28	54	34	.....	.....	.....	3.44	+.5	4	6.8	ne.	25	w.	15	17	11	2	3.4	.0	.0
Elkins	1,947	59	78	28.09	30.14	+.06	60.2	−2.8	88	1	73	33	18	48	39	54	52	89	3.83	+.7	10	4.2	n.	19	sw.	19	9	15	6	5.1	.0	.0
Parkersburg	637	77	84	29.40	30.08	.00	64.6	−2.7	92	2	76	36	18	53	39	57	54	77	1.30	−1.5	6	4.9	se.	19	nw.	16	11	16	3	4.0	.0	.0
Pittsburgh [1]	1,273	39	54	28.75	30.09	+.01	62.6	−3.8	93	2	73	35	18	52	33	54	50	71	.57	−2.0	5	9.0	s.	26	sw.	15	8	14	8	5.0	.0	.0
Lower Lake Region							61.7	−1.2										70	1.81	−1.2										4.9		
Buffalo	768	243	280	29.24	30.06	.00	61.4	−1.0	85	24	69	39	20	54	28	55	50	71	1.09	−1.8	9	13.0	s.	45	sw.	15	9	14	7	5.1	.0	.0
Canton	448	10	61	29.56	30.03	.....	58.6	−.7	89	1	69	35	27	48	32	53	49	77	1.98	−1.4	9	7.8	sw.	25	w.	14	12	9	9	5.1	.0	.0
Ithaca	836	77	100	29.17	30.07	.....	59.8	−1.8	92	1	71	34	18	48	35	53	49	75	1.86	−1.2	14	7.9	nw.	27	s.	15	9	8	13	5.5	.0	.0
Oswego	335	71	85	29.68	30.05	−.01	60.4	−.8	90	3	69	41	18	52	28	54	50	74	.98	−1.7	9	8.9	s.	27	n.	13	8	11	11	6.0	.0	.0
Rochester	523	86	102	29.51	30.08	+.02	61.2	−1.2	90	2	70	41	18	52	30	53	48	67	.50	−2.0	6	8.1	sw.	28	w.	11	11	11	8	5.0	.0	.0
Syracuse	596	65	79	29.43	30.07	.00	61.4	−.4	91	2	70	40	27	52	29	.....	.....	.....	1.39	−1.3	9	6.8	s.	21	sw.	11	12	9	9	5.0	.0	.0
Erie	714	130	166	29.31	30.08	+.02	62.7	−.9	89	3	71	42	27	55	28	55	51	70	2.56	−.8	5	12.1	s.	32	w.	11	9	16	5	4.7	.0	.0
Cleveland	762	267	318	29.26	30.08	+.02	63.3	−.6	87	2	70	45	18	56	27	55	49	63	.99	−2.3	5	13.9	s.	37	nw.	11	9	14	7	4.6	.0	.0
Sandusky	629	5	67	29.40	30.08	+.02	63.8	−1.5	94	3	74	40	28	54	33	.....	.....	.....	3.51	+.6	5	8.1	s.	21	sw.	14	13	9	8	4.8	.0	.0
Toledo	628	79	87	29.42	30.10	+.04	62.8	−1.6	90	3	72	40	20	53	29	55	50	68	2.23	−.6	3	8.3	sw.	24	w.	15	15	9	6	3.8	.0	.0
Fort Wayne	857	69	84	29.17	30.09	.....	62.6	−2.6	91	2	73	40	17	53	33	55	50	69	2.88	−.2	6	7.8	s.	31	sw.	18	10	14	6	4.2	.0	.0
Detroit [1]	626	5	78	29.40	30.08	+.02	61.8	−1.7	93	3	72	38	20	51	30	54	50	71	1.80	−1.1	5	9.0	nw.	27	nw.	11	11	11	8	4.9	.0	.0
Upper Lake Region							59.8	+0.3										74	3.72	+0.4										5.4		
Alpena	609	13	89	29.40	30.06	+.03	58.0	+.4	91	3	67	35	27	49	30	52	49	79	7.43	+4.4	12	10.1	nw.	32	nw.	19	5	15	10	5.8	.0	.0
Escanaba	612	41	49	29.38	30.04	+.03	56.4	−.7	86	3	65	33	26	48	27	52	49	80	7.58	+4.3	12	7.9	s.	23	n.	10	8	9	13	6.0	.0	.0
Grand Rapids	707	70	244	29.31	30.07	+.02	63.2	+.5	92	2	73	38	27	53	31	54	50	68	2.44	−1.1	11	10.5	sw.	39	s.	10	11	11	8	4.8	.0	.0
Lansing	878	5	90	29.13	30.08	.....	60.0	−1.4	89	3	71	33	27	49	31	54	51	80	1.28	−1.6	6	7.6	s.	23	nw.	15	7	16	7	5.0	.0	.0
Ludington	637	5	54	29.36	30.05	.....	60.7	+1.4	85	2	69	36	27	53	27	54	51	.....	3.42	+.2	12	.....	s.	.....	.....	.....	16	8	6	.....	.0	.0
Marquette	734	44	69	29.23	30.03	+.03	56.6	−.9	91	22	65	39	16	48	36	51	48	75	3.36	+.1	14	8.2	nw.	32	sw.	3	4	13	13	6.2	.0	.0
Sault Sainte Marie	614	11	52	29.37	30.07	+.05	55.8	+.3	82	3	64	37	27	47	31	51	47	79	5.24	+1.0	14	7.0	se.	24	nw.	19	11	6	13	5.6	T	.0
Chicago	673	7	131	29.35	30.08	+.04	65.1	−.1	93	2	74	44	17	57	30	56	51	67	1.89	−1.2	8	10.0	s.	28	sw.	18	9	14	7	4.8	.0	.0
Green Bay	617	109	141	29.38	30.04	+.02	61.6	+1.2	94	2	72	37	26	51	32	53	48	68	2.84	−.7	10	10.5	s.	30	n.	10	8	11	11	5.5	.0	.0
Milwaukee	681	97	221	29.32	30.06	+.03	63.8	+1.3	94	2	72	42	26	55	31	55	49	64	1.14	−2.2	7	12.9	sw.	35	sw.	18	12	12	6	4.6	.0	.0
Duluth	1,133	5	47	28.79	30.00	+.02	56.2	+1.1	84	1	65	33	19	47	29	50	47	80	4.30	+1.0	14	10.8	nw.	32	nw.	9	6	13	11	6.1	.0	.0
North Dakota							53.8	+1.6										65	1.46	−0.1										6.6		
Moorhead, Minn	940	50	58	28.99	30.00	+.04	59.0	+.8	96	21	70	33	16	48	41	51	46	69	1.56	−.7	8	8.4	s.	25	nw.	14	9	12	9	5.8	.0	.0
Bismarck	1,674	8	57	28.22	30.00	+.06	60.4	+2.3	94	2	73	32	25	48	44	51	44	61	1.19	.0	6	8.4	ne.	30	nw.	6	12	11	7	4.5	.0	.0
Devils Lake	1,478	11	44	28.44	30.01	+.07	56.4	+.5	91	2	69	32	26	44	43	48	42	70	1.80	+.2	10	8.8	nw.	27	nw.	14	10	12	8	5.4	.0	.0
Williston	1,878	42	50	28.03	30.00	+.07	59.4	+2.8	87	2	72	30	28	47	41	49	41	60	1.31	+.2	6	8.5	se.	27	se.	29	15	10	5	4.0	.0	.0
Upper Mississippi Valley							66.2	+0.9										65	2.20	−1.4										3.9		
Minneapolis-St. Paul Minn	919	105	208	29.04	30.02	+.03	63.5	+2.1	97	2	74	37	19	53	35	54	47	61	1.67	−1.5	8	10.3	s.	31	nw.	14	8	17	5	4.6	.0	.0
La Crosse	714	11	48	29.28	30.04	+.03	63.6	+1.4	98	2	75	35	26	53	31	55	51	71	1.91	−2.1	7	5.2	s.	15	sw.	23	15	9	6	4.1	.0	.0
Madison	974	70	78	29.01	30.04	+.01	63.0	+.6	92	2	73	39	26	53	34	54	49	67	5.48	+1.8	8	8.2	s.	33	s.	1	12	12	6	4.6	.0	.0
Charles City	1,015	10	51	28.97	30.06	+.06	63.4	+2.4	94	22	76	32	16	51	38	54	48	67	2.00	−1.7	6	6.2	se.	21	sw.	23	13	12	5	4.3	.0	.0
Davenport	606	66	161	29.41	30.07	+.04	66.8	+1.2	94	2	78	40	16	56	34	56	50	62	2.06	−1.5	6	9.2	sw.	25	nw.	15	15	12	3	3.9	.0	.0
Des Moines	861	5	99	29.14	30.04	+.02	67.5	+1.9	98	22	80	35	26	55	40	57	50	63	1.41	−2.3	4	8.7	s.	25	s.	30	18	9	3	3.3	.0	.0
Dubuque	699	60	79	29.31	30.05	+.02	64.8	+.8	95	2	76	38	26	53	34	55	49	66	1.87	−2.1	7	4.4	s.	16	nw.	10	13	12	5	4.3	.0	.0
Keokuk	614	64	78	29.40	30.05	+.02	67.4	−.1	94	1	78	40	27	56	36	57	50	60	1.47	−2.4	3	6.9	se.	20	sw.	18	16	6	8	4.1	.0	.0
Cairo	358	87	93	29.67	30.04	−.01	70.2	−1.3	94	1	79	47	28	61	29	62	58	72	3.18	+.3	6	7.5	n.	31	nw.	10	16	4	10	4.3	.0	.0
Peoria	609	11	45	29.42	30.08	+.04	65.8	+1.5	94	1	78	34	27	53	38	56	52	70	1.14	−2.9	3	6.0	s.	17	sw.	18	21	6	3	2.7	.0	.0
Springfield, Ill	636	5	191	29.39	30.06	+.01	67.6	.0	94	1	79	42	26	56	35	57	51	65	2.16	−1.5	5	10.5	s.	25	nw.	24	16	8	6	3.7	.0	.0
St. Louis	568	179	303	29.45	30.05	+.01	70.3	−.2	92	22	80	47	27	60	32	59	53	60	2.02	−1.4	5	11.0	s.	29	sw.	24	16	9	5	3.4	.0	.0
Missouri Valley							68.8	+2.6										58	1.23	−2.0										3.7		
Columbia, Mo	784	6	66	29.22	30.04	+.01	69.9	+1.7	97	22	82	41	26	58	34	.....	.....	.....	1.92	−2.4	4	7.3	e.	21	nw.	10	14	11	5	4.2	.0	.0
Kansas City [1]	750	32	45	29.23	30.02	.00	72.0	+3.1	100	22	84	39	26	60	37	60	52	58	.21	−4.4	3	8.6	ne.	27	sw.	18	14	10	6	4.0	.0	.0
St. Joseph	967	11	49	29.01	30.03	.....	70.9	.....	99	22	83	37	26	59	35	59	51	57	.82	−3.1	3	7.9	s.	21	nw.	24	24	2	4	2.5	.0	.0
Springfield, Mo	1,324	98	104	28.65	30.04	+.01	70.0	+1.1	93	22	80	42	26	61	27	61	55	67	2.63	−.9	7	9.0	se.	21	se.	28	14	9	7	4.1	.0	.0
Topeka	987	65	87	28.98	30.02	.....	72.0	+3.3	102	3	84	40	26	60	35	60	53	58	.43	−3.4	6	8.7	s.	26	sw.	23	12	14	4	4.2	.0	.0
Lincoln	1,189	11	81	28.76	30.00	+.01	70.3	+3.9	99	22	83	39	26	58	38	58	48	52	1.11	−1.9	8	9.8	s.	32	nw.	23	16	7	7	4.0	.0	.0
Omaha [1]	982	31	44	28.98	30.02	+.02	68.8	+2.0	100	3	82	37	26	56	39	57	50	60	.80	−2.4	5	9.9	s.	34	s.	23	16	9	5	3.4	.0	.0
Valentine	2,598	47	54	27.34	30.02	+.06	65.3	+2.8	98	2	79	32	25	52	43	53	45	55	.93	−.4	4	9.3	s.	25	sw.	20	16	9	5	3.8	.0	.0
Sioux City	1,138	64	106	28.81	30.01	+.03	66.6	+3.2	97	2	78	36	16	55	41	56	48	58	2.63	−.4	7	8.9	s.	31	se.	23	19	6	5	3.6	.0	.0
Huron	1,307	59	74	28.62	30.01	+.05	64.0	+2.7	99	2	77	32	26	51	42	53	46	61	.80	−.8	4	9.6	se.	28	sw.	21	18	8	4	3.1	.0	.0
Northern Slope							60.7	+3.8										55	0.85	−0.4										4.4		
Missoula	3,263	80	91	.....	.....	.....	62.6	+7.2	91	3	77	31	30	48	45	.....	.....	.....	.57	−.9	9	6.6	e.	35	s.	4	15	6	9	4.1	T	.0
Havre	2,507	11	67	27.40	30.02	+.08	58.4	+2.0	88	17	72	30	24	45	46	49	40	60	1.07	−.2	7	7.5	e.	23	nw.	14	16	6	8	4.0	T	.0
Helena	4,124	85	111	25.88	30.03	+.06	58.6	+2.0	86	2	71	31	30	47	37	47	38	51	2.25	+1.0	11	7.4	sw.	30	se.	8	10	11	9	5.1	.3	.0
Kalispell	2,973	48	56	26.99	30.00	+.04	58.1	+4.6	86	17	72	32	25	45	37	48	40	58	.91	−.3	9	5.4	w.	18	se.	4	15	2	13	4.7	.0	.0
Miles City	2,371	48	55	27.49	29.95	.00	63.2	+2.0	99	19	76	33	25	50	46	52	43	54	.77	−.3	7	6.0	ne.	28	nw.	22	13	10	7	4.5	T	.0
Rapid City	3,259	50	58	26.67	29.98	+.02	64.2	+3.8	97	1	77	36	24	52	45	53	44	52	.67	−.5	3	7.9	w.	35	nw.	29	17	7	6	3.6	.0	.0
Cheyenne [1]	6,144	5	39	24.07	29.99	+.03	60.4	+3.4	88	18	76	26	25	45	42	47	38	53	.49	−.7	8	10.0	nw.	35	nw.	9	10	15	5	4.6	.1	.0
Lander	5,372	60	68	24.73	30.01	+.05	60.0	+4.3	87	19	76	20	25	44	44	47	37	48	.11	−.8	3	5.1	sw.	32	sw.	29	15	10	5	4.0	.9	.0
Sheridan	3,790	10	47	26.15	30.01	.....	60.7	.....	94	19	77	27	25	44	51	49	42	60	.50	−.8	3	4.7	nw.	25	nw.	29	16	9	5	3.9	T	.0
Yellowstone Park	6,241	12	46	23.99	30.10	+.13	54.4	+4.3	81	18	69	24	25	40	41	43	34	54	1.11	−.1	10	7.0	sw.	32	sw.	29	14	9	7	4.6	.6	.0
North Platte	2,821	11	51	27.12	30.01	+.04	66.8	+4.7	96	2	80	38	27	54	45	56	50	62	.89	−.5	8	7.0	s.	26	n.	23	18	5	7	4.0	.0	.0

See footnotes at end of table.

TABLE 2.—*Climatological data for Weather Bureau stations, September 1937*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice, on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Middle Slope							**70.6**	**+2.5**										**55**	**1.35**	**−0.7**										**3.8**		
Denver	5,292	106	113	24.82	29.99	+0.03	66.1	+3.2	90	19	79	35	25	54	35	51	39	44	.56	−.4	5	7.3	s.	31	n.	13	14	13	3	4.1	T	0.0
Pueblo	4,685	80	86	25.38	29.99	+.03	67.6	+3.0	91	1	81	36	26	54	47	53	43	49	.35	−.4	4	7.0	nw.	31	nw.	23	18	8	4	3.6	0.0	.0
Concordia	1,392	50	58	28.56	30.01	+.02	71.6	+3.3	101	3	83	44	26	60	38	59	51	57	1.64	−1.0	7	8.4	s.	23	s.	23	15	11	4	3.9	.0	.0
Dodge City	2,509	10	86	27.43	29.99	+.01	71.4	+2.0	96	3	84	44	25	59	41	58	51	57	.84	−1.1	5	11.7	se.	32	sw.	29	16	11	3	3.5	.0	.0
Wichita	1,358	85	93	28.59	30.00	.00	72.0	+1.4	96	3	82	46	26	62	31	62	55	61	1.80	−1.3	7	10.1	se.	32	s.	23	16	9	5	3.7	.0	.0
Oklahoma City	1,214	10	47	28.73	29.99	.00	75.0	+2.2	95	21	85	47	26	65	33	64	58	64	2.90	−.2	8	8.7	s.	24	s.	28	14	10	6	4.0	.0	.0
Southern Slope							**76.6**	**+3.1**										**57**	**2.01**	**−0.5**										**3.8**		
Abilene	1,738	10	52	28.20	29.97	+.01	79.4	+4.1	99	3	91	51	26	68	31	64	56	52	1.52	−1.2	4	8.6	s.	25	s.	28	16	8	6	3.7	.0	.0
Amarillo	3,676	10	49	26.33	29.98	+.02	73.1	+3.8	99	3	84	45	26	62	35	60	53	58	2.61	+.3	8	9.1	s.	27	sw.	13	13	12	5	4.2	.0	.0
Del Rio	960	63	71	28.94	29.90	−.04	81.3	+2.1	100	2	91	58	26	71	26	68	61	56	.41	−2.6	3	9.1	se.	24	e.	3	13	11	6	4.4	.0	.0
Roswell	3,566	75	85	26.42	29.96	+.04	72.8	+2.5	98	3	85	48	27	60	39	61	54	62	3.51	+1.4	11	6.7	s.	31	w.	6	18	10	2	2.9	.0	.0
Southern Plateau							**74.6**	**+3.8**										**51**	**1.46**	**+0.4**										**2.7**		
El Paso	3,778	82	101	26.21	29.90	+.02	76.9	+3.0	98	4	88	55	26	66	32	62	53	51	.48	−.8	4	7.5	e.	24	n.	5	18	10	2	3.2	.0	.0
Albuquerque [1]	4,972	5	39	25.12	29.92	------	69.9	+2.0	93	1	84	43	27	55	44	56	48	55	.87	.0	9	7.5	n.	40	nw.	30	19	8	3	3.4	.0	.0
Santa Fe	7,013	38	53	23.37	29.97	+.04	63.9	+3.0	84	1	76	39	26	52	35	50	41	51	2.71	+1.3	7	5.4	e.	18	w.	3	14	12	4	4.0	.0	.0
Flagstaff	6,907	10	59	23.46	29.90	+.01	60.5	+5.0	84	12	77	34	26	44	45	49	----	58	1.83	+.4	7	7.0	n.	32	w.	29	5	21	4	----	.0	.0
Phoenix	1,107	39	51	28.68	29.80	−.01	86.9	+4.2	106	9	100	66	26	74	37	68	58	43	1.17	+.4	6	5.6	e.	30	ne.	10	24	5	1	2.2	.0	.0
Yuma	141	9	54	29.63	29.77	−.01	89.6	+5.9	112	14	104	61	30	76	35	72	63	49	1.71	+1.4	2	5.3	s.	24	ne.	10	27	3	0	.7	.0	.0
Independence	3,957	5	26	25.95	29.92	+.06	71.6	+3.6	98	11	90	44	30	54	45	51	30	----	.02	−.1	1	----	s.	----	-------	---	26	4	0	----	.0	.0
Middle Plateau							**65.2**	**+3.8**										**37**	**0.45**	**−0.2**										**2.3**		
Reno	4,527	61	76	25.48	29.94	−.01	64.6	+4.1	94	14	82	40	25	47	44	48	33	37	.05	−.2	1	6.1	sw.	24	sw.	4	26	3	1	1.2	.0	.0
Tonopah	6,090	12	20	------	------	------	67.6	------	87	10	79	44	20	56	26	47	29	26	1.38	------	2	----	se.	----	-------	---	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.63	29.96	+.03	62.4	+3.2	95	15	83	28	24	42	55	45	29	33	.09	−.3	2	7.3	ne.	23	nw.	22	24	6	0	1.8	.0	.0
Modena	5,473	10	43	24.67	29.92	.00	64.6	+4.6	91	16	82	33	26	47	45	49	36	44	.72	−.1	4	9.5	w.	38	s.	19	21	7	2	2.4	.0	.0
Salt Lake City [1]	4,227	32	46	25.75	29.93	−.02	67.4	------	94	18	83	35	25	52	44	52	38	40	.83	------	7	9.7	se.	44	w.	8	18	8	4	3.0	.0	.0
Grand Junction	4,602	60	68	25.43	29.97	+.02	69.4	+3.2	91	15	83	42	26	56	36	54	42	43	.93	.0	6	6.5	se.	27	se.	19	17	8	5	3.3	.0	.0
Northern Plateau							**64.3**	**+4.0**										**46**	**0.48**	**−0.3**										**3.0**		
Baker	3,471	36	54	26.48	30.03	+.04	60.2	+4.2	95	15	78	30	23	43	47	48	37	47	.16	−.6	5	5.8	s.	22	s.	4	19	6	5	3.1	.0	.0
Boise	2,739	79	87	27.16	29.98	+.01	65.6	+3.7	95	3	80	35	24	51	42	51	39	41	.39	−.1	3	5.1	nw.	21	se.	4	20	9	1	2.4	.0	.0
Pocatello	4,477	60	68	25.51	29.96	.00	64.1	+3.9	90	17	79	32	25	49	40	49	35	39	.62	−.2	8	8.3	se.	30	sw.	4	19	10	1	2.8	.0	.0
Spokane	1,929	101	110	27.97	30.00	+.02	62.6	+3.4	93	15	76	36	24	49	40	51	41	52	.62	−.3	4	5.1	s.	23	se.	29	16	8	6	3.7	.0	.0
Walla Walla	991	57	65	28.92	29.98	−.02	67.6	+3.8	94	14	80	43	25	55	36	54	42	44	.20	−.8	2	5.3	s.	17	sw.	28	20	5	5	3.1	.0	.0
Yakima	1,076	58	67	28.85	29.99	------	65.8	+4.7	94	15	78	37	25	53	37	54	45	51	.88	+.4	3	6.4	nw.	21	nw.	20	18	7	5	3.2	.0	.0
North Pacific Coast Region							**61.0**	**+1.8**										**75**	**2.02**	**−0.2**										**5.2**		
North Head	211	11	56	29.85	30.08	+.05	57.8	+1.3	91	14	62	47	29	53	36	55	54	90	2.20	−.8	10	13.3	nw.	64	se.	30	10	7	13	5.8	.0	.0
Seattle	125	90	321	29.91	30.04	+.03	61.0	+2.9	92	14	68	44	23	54	34	56	52	74	2.43	+.7	6	6.7	n.	22	s.	30	7	12	11	5.6	.0	.0
Tatoosh Island	86	10	54	29.97	30.06	+.05	54.8	+1.8	71	14	59	46	24	51	17	52	51	89	2.34	−2.3	9	10.3	s.	42	s.	30	7	6	17	6.7	.0	.0
Medford [1]	1,329	29	58	28.59	29.98	------	65.2	+1.9	102	14	82	37	23	48	49	54	44	57	1.15	+.6	3	----	nw.	----	-------	---	17	9	4	2.9	.0	.0
Portland, Oreg	153	68	106	29.88	30.03	.00	63.8	+2.1	97	14	72	44	23	55	35	57	53	71	2.06	+.1	4	5.8	nw.	15	se.	30	11	11	8	5.3	.0	.0
Roseburg	510	45	76	29.48	30.02	.00	63.4	+.5	101	14	77	38	23	50	46	56	50	68	1.95	+.7	5	4.2	n.	17	sw.	30	10	13	7	4.8	.0	.0
Middle Pacific Coast Region							**66.2**	**+1.2**										**63**	**0.05**	**−0.6**										**3.6**		
Eureka	62	73	89	29.96	30.03	+.02	56.4	+.5	72	13	62	45	22	51	20	53	51	86	.19	−.8	6	5.7	nw.	21	s.	30	8	7	15	6.2	.0	.0
Redding [1]	722	20	34	------	------	------	75.3	+1.8	104	13	88	54	29	63	38	56	39	33	.02	−.8	1	7.8	nw.	28	nw.	18	20	6	4	2.6	.0	.0
Sacramento	66	92	115	29.83	29.90	+.01	71.6	+2.3	102	16	86	51	29	57	43	58	48	50	.00	−.4	0	6.8	s.	23	s.	28	24	6	0	.9	.0	.0
San Francisco	155	112	132	29.78	29.94	.00	61.4	+.5	89	25	68	50	10	54	34	56	54	83	T	−.4	0	9.3	w.	24	w.	10	13	11	6	4.7	.0	.0
South Pacific Coast Region							**72.3**	**+2.5**										**64**	**T**	**−0.2**										**2.3**		
Fresno	327	97	105	29.54	29.89	+.02	75.2	+1.8	105	16	90	53	23	60	36	60	49	46	T	−.2	0	6.2	nw.	18	nw.	18	28	1	1	.8	.0	.0
Los Angeles	338	159	191	29.54	29.89	+.01	72.4	+3.4	95	12	82	59	1	63	26	62	57	67	.0	−.2	0	5.1	sw.	15	w.	25	20	6	4	2.7	.0	.0
San Diego	87	62	70	29.80	29.89	.00	69.4	+2.3	90	12	75	60	24	64	21	64	61	80	T	−.1	0	6.7	nw.	18	nw.	8	16	11	3	3.5	.0	.0
West Indies																																
San Juan, P. R	82	9	54	29.83	29.91	------	81.6	+1.1	91	25	86	74	1	77	15	----	----	----	2.73	−3.2	13	8.5	e.	24	ne.	7	14	15	1	3.7	.0	.0
Panama Canal																																
Balboa Heights	118	6	92	------	[2] 29.85	+.03	79.9	+.1	90	17	86	72	27	74	16	----	----	[2] 87	10.89	+2.7	24	4.4	nw.	17	s.	27	0	15	15	7.4	.0	.0
Cristobal	[3] 36	6	97	------	[2] 29.86	+.03	81.5	+1.1	91	12	87	74	27	76	14	76	75	[2] 84	14.09	+1.6	23	5.2	se.	23	nw.	22	0	6	24	8.4	.0	.0
Alaska																																
Fairbanks	454	11	87	[2] 29.36	[2] 29.88	------	47.8	+4.4	77	5	59	25	30	37	37	43	38	70	.34	−1.0	7	5.3	ne.	24	s.	11	2	11	17	7.4	.0	.0
Juneau	80	96	116	[2] 29.94	[2] 30.03	------	52.7	+2.5	75	4	58	38	28	48	28	49	45	78	9.92	−.5	20	7.1	s.	39	ne.	30	3	5	22	8.0	.0	.0
Nome	22	5	32	[2] 29.79	[2] 29.81	------	43.8	+2.2	59	10	50	22	20	38	23	42	39	82	5.38	+2.6	17	8.6	n.	28	n.	11	3	7	20	7.7	.0	.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.98	[2] 30.02	------	77.8	−.4	85	1	83	71	26	73	13	70	67	70	1.67	+.4	13	8.7	e.	22	ne.	14	10	19	1	4.1	.0	.0

[1] Observations taken at airport.
[2] Observations taken hourly.
[3] Pressure not reduced to mean of 24 hours.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, September 1937*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
Cape Race, Newfoundland	99												
Sydney, Cape Breton Island	48	29.93	29.99	−0.05	61.2	+4.2	69.2	53.3	87	38	8.14	+4.77	0.0
Halifax, Nova Scotia	88	29.77	30.03	−.02	60.4	+2.1	67.6	53.1	82	45	5.33	+1.59	0
Yarmouth, Nova Scotia	65	29.91	30.02	−.04	58.3	+2.3	66.2	50.4	83	39	4.24	+.73	.0
Charlottetown, Prince Edward Island	38	29.93	30.01	−.01	60.5	+3.6	67.7	53.3	84	44	3.59	−.10	.0
Chatham, New Brunswick	28	29.87	29.97	.00	57.0	+.6	66.9	47.0	84	35	6.04	+3.01	.0
Father Point, Quebec	20	29.95	29.97	−.01	50.6	+.9	56.9	44.3	76	31	2.74	−.24	.0
Quebec, Quebec	296	29.70	30.02	.00	56.8	+1.2	64.3	49.4	85	38	5.85	+1.83	.0
Doucet, Quebec	1,236				48.8	+.4	59.9	37.7	83	21	6.17	+1.82	.0
Montreal, Quebec	187												
Ottawa, Ontario	236												
Kingston, Ontario	285	29.74	30.04	−.01	59.5	−.5	66.7	52.3	83	39	1.62	−1.18	.0
Toronto, Ontario	379	29.66	30.06	+.01	60.1	−.3	69.9	50.2	90	37	1.39	−1.57	.0
Cochrane, Ontario	930				50.4	−1.0	60.4	40.5	83	29	4.80	+1.73	T
White River, Ontario	1,244	29.69	30.04	+.05	48.9	−1.1	61.1	36.8	78	23	3.01	−.02	.2
London, Ontario	808				57.4	−3.1	68.6	46.2	91	32	3.24	+.36	.0
Southampton, Ontario	656	29.34	30.06	+.02	57.7	−1.5	66.8	48.5	87	34	3.50	+.62	.0
Parry Sound, Ontario	688	29.36	30.06	+.03	57.1	−.3	65.9	48.3	88	36	5.51	+1.90	.0
Port Arthur, Ontario	644	29.31	30.02	+.04	51.8	−1.4	62.3	41.3	85	28	2.23	−1.15	.0
Winnipeg, Manitoba	760	29.17	30.00	+.03	53.7	−.5	64.8	42.6	87	26	2.29	+.03	.0
Minnedosa, Manitoba	1,690	28.22	30.04	+.10	52.1	+.1	64.6	39.7	85	21	1.29	−.31	T
Le Pas, Manitoba	860				49.9	+.7	60.6	39.2	80	27	1.85	+.04	.0
Qu'Appelle, Saskatchewan	2,115	27.76	30.04	+.08	53.3	+1.4	65.6	41.0	86	24	2.36	+.73	9.8
Moose Jaw, Saskatchewan	1,759				55.5	+2.0	68.0	43.0	89	25	1.24	−.03	5.0
Swift Current, Saskatchewan	2,392	27.48	30.04	+.09	56.4	+3.1	68.3	44.4	89	29	.89	−.38	.0
Medicine Hat, Alberta	2,365	27.54	30.02	+.09	57.7	+1.7	70.8	44.5	88	30	1.14	−.02	.0
Calgary, Alberta	3,540												
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450	28.50	30.06	+.12	52.8	+2.6	64.2	41.8	86	29	1.71	+.16	.0
Battleford, Saskatchewan	1,592	28.30	30.04	+.10	53.0	+1.5	68.4	37.5	90	22	.84	−.52	.0
Edmonton, Alberta	2,150	27.76	30.06	+.15	52.7	+2.5	64.2	41.2	84	29	1.94	+.63	.0
Kamloops, British Columbia	1,262	28.72	30.06	+.08	63.1	+4.5	76.2	50.0	90	33	.19	−.63	.0
Victoria, British Columbia	230	29.80	30.05	+.06	58.0	+2.0	65.3	50.6	88	45	.38	−1.27	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20				55.3	+1.7	60.8	49.8	77	39	5.22	+.33	.0
Prince Rupert, British Columbia	170				55.8	+2.2	63.0	48.5	76	41	3.12	−4.67	.0
St. George's, Bermuda	158		29.99	−.08	79.7	+1.9	85.6	73.8	92	66	6.14	+.58	.0
LATE REPORTS FOR AUGUST 1937													
Cape Race, Newfoundland	99				60.9	+4.3	67.1	54.7	76	43	3.13	−0.88	0.0
Father Point, Quebec	20	29.95	29.97	+0.05	59.8	+4.1	67.9	51.6	76	44	3.95	+.84	.0
Quebec, Quebec	296	29.70	30.02	+.07	69.8	+6.2	77.9	61.8	89	50	9.61	+5.78	.0
Ottawa, Ontario	236	29.96	30.00	+.06	70.6	+4.9	82.0	59.3	92	48	3.52	+.64	.0
Calgary, Alberta	3,540	26.30	29.94	.00	57.2	−1.5	70.4	44.1	83	35	1.98	−.35	.0
Kamloops, British Columbia	1,262	28.68	30.02	+.10	64.0	−4.3	75.6	52.5	91	40	.88	−.40	.0

TABLE 3A.—*Monthly station and sea-level pressures*[1] *for Canadian stations reduced to 24-hour means*

Station	Altitude above mean sea level, Jan. 1, 1919	June 1937, pressure			July 1937, pressure			August 1937, pressure		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal
	Feet	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Sydney, Cape Breton Island	48	29.87	29.92	−0.03	29.85	29.91	−0.03	29.96	30.01	+0.03
Halifax, Nova Scotia	88	29.67	29.93	−.03	29.69	29.95	−.01	29.81	30.07	+.08
Yarmouth, Nova Scotia	65	29.81	29.91	−.05	29.86	29.97	+.01	29.97	30.07	+.07
Charlottetown, Prince Edward Island	38	29.85	29.93	.00	28.85	29.93	+.01	29.95	30.03	+.07
Chatham, New Brunswick	28	29.79	29.90	−.01	29.79	29.89	−.01	29.89	29.99	+.04
Father Point, Quebec	20	29.83	29.85	−.03	29.83	29.85	−.01			
Quebec, Quebec	296	29.58	29.90	.00	29.60	29.92	+.02			
Montreal, Quebec	187	29.70	29.90	−.01	29.74	29.94	+.03	29.84	30.04	+.08
Ottawa, Ontario	236	29.64	29.88	−.04	29.66	29.90	−.02			
Kingston, Ontario	285	29.60	29.92	−.02	29.61	29.93	−.01	29.74	30.04	+.06
Toronto, Ontario	379				29.54	29.94	−.02	29.64	30.06	+.07
White River, Ontario	1,244	28.60	29.92	.00	28.64	29.96	+.04	28.70	30.02	+.06
Southampton, Ontario	656	29.24	29.94	−.01	29.24	29.94	−.04	29.36	30.06	+.06
Parry Sound, Ontario	688				29.26	29.96	+.02	29.38	30.06	+.08
Port Arthur, Ontario	644	29.28	29.98	+.05	29.26	29.97	+.04	29.28	29.99	+.02
Winnipeg, Manitoba	760	29.07	29.89	−.02	29.10	29.91	−.02	29.07	29.88	−.08
Minnedosa, Manitoba	1,690				28.16	29.94	+.04	28.11	29.88	−.05
Qu'Appelle, Saskatchewan	2,115	27.64	29.89	+.02	27.68	29.91	−.01	27.64	29.88	−.06
Swift Current, Saskatchewan	2,392	27.38	29.90	+.04	27.40	29.90	.00	27.40	29.92	.00
Medicine Hat, Alberta	2,365	27.46	29.92	+.06	27.46	29.90	+.02	27.44	29.88	−.02
Calgary, Alberta	3,540	26.32	29.96	+.08	26.36	29.98	+.06			
Prince Albert, Saskatchewan	1,450	28.36	29.89	+.01	28.40	29.92	+.01	28.34	29.86	−.07
Battleford, Saskatchewan	1,592	28.16	29.88	+.01	28.22	29.92	+.01	28.16	29.88	−.05
Edmonton, Alberta	2,150	27.64	29.90		27.68	29.94		27.62	29.88	
Kamloops, British Columbia	1,262	28.64	29.98	+.06	28.68	30.00	+.06			
Victoria, British Columbia	230				29.83	30.07	+.03	29.81	30.05	+.03

[1] The values published for June, July, and August 1937 were not corrected for 24-hour means.

TABLE 4.—*Severe local storms, September 1937*

(Compiled by Mary O. Souder from reports submitted by Weather Bureau officials)

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Alabama, southeast portion	Aug. 31–Sept. 1.				$42,500	Heavy rain	Damage to property and crops along the Choctawhatchee River.
Mays, Ind	1	10:45 a. m.	33	0		Tornado	Several hundred dollars' damage to packing plant.
Madison, Wis	1	P. m.				Thunderstorm	Streets flooded; electrical and transmission lines interrupted; considerable damage reported.
Phoenix, Ariz., vicinity of	1			0	2,500	Tornado	Property damaged.
Duluth, Minn., and vicinity	1–2					Thundersquall	Sewers overflowed and many basements flooded; highways and bridges damaged; traffic delayed; number of places struck by lightning and power lines affected. The Steamer *Montauk* blown ashore in the St. Louis River off Indian Point.
Alpena, Mich	2–3					Heavy rain	Sewers inadequate; basements flooded; sections of roads washed out.
Maxwell to Cozard, Nebr	3	5:50 p. m.	[1] 4		200,000	Hail and wind	Property damage.
Elbridge, N. Y	3				7,500	Electrical	Barn destroyed; cattle killed.
Missoula, Mont., vicinity of	4	P. m.		1	10,000	Wind and dust	1 person killed by a falling tree; hundreds of chickens killed; buildings, trees, power, and telephone lines damaged; loss to fruit.
Hartford, Conn., and vicinity	4				12,000	Thunderstorm	Several persons injured by falling debris; electric wires down; property destroyed by fire.
Deadwood and Lead, S. Dak., vicinity of.	5	6:30–6:40 p. m.				Heavy hail	Damage to car tops, roofs, and trees; path narrow.
Billings, Mont., and vicinity	5	P. m.				Hail and rain	Portion of the Northern Pacific Ry. grading washed out delaying trains for several hours; 20 feet of highwny damaged; loss to bean and beet crops not estimated.
Anderson County, S. C	7	do			1,000	Electrical	House damaged; barn destroyed.
Kingman, Kans	8				20,500	Heavy rain	5.35 inches of rain caused the Ninnescah River to overflow, causing damage of $12,500 to buildings and roads and $8,000 loss to matured and prospective crops.
Benton County, Ark	8–9				25,000	do	Many roads, culverts, and bridges washed out.
Oatsville, Ind., vicinity of	10	3:45 p. m.	33–66	0	3,000–4,000	Tornado	Property damaged.
Indianapolis, Ind	10	5:01–6:58 p. m.				Thunderstorm	Basements and streets flooded; power lines and residences damaged by lightning.
Bradfordton, Ill	10				15,000	Electrical	Grain elevator burned.
St. Johns County, Fla.[2]	20		67	0	5,000–7,500	Tornado	Damage to shrubbery and outbuildings; path about 1,000 yards long.
St. Paul, Minn	23	P. m.			1,000	Thunderstorm	Residence damaged by lightning.
Rushville, Ill., vicinity of	23				500	Wind	Damage to barn and small buildings.

[1] Miles instead of yards.
[2] From press reports.

U. S. GOVERNMENT PRINTING OFFICE: 1937

Chart I. Departure (°F.) of the Mean Temperature from the Normal, September 1937

Chart I. Departure (°F.) of the Mean Temperature from the Normal, September 1937

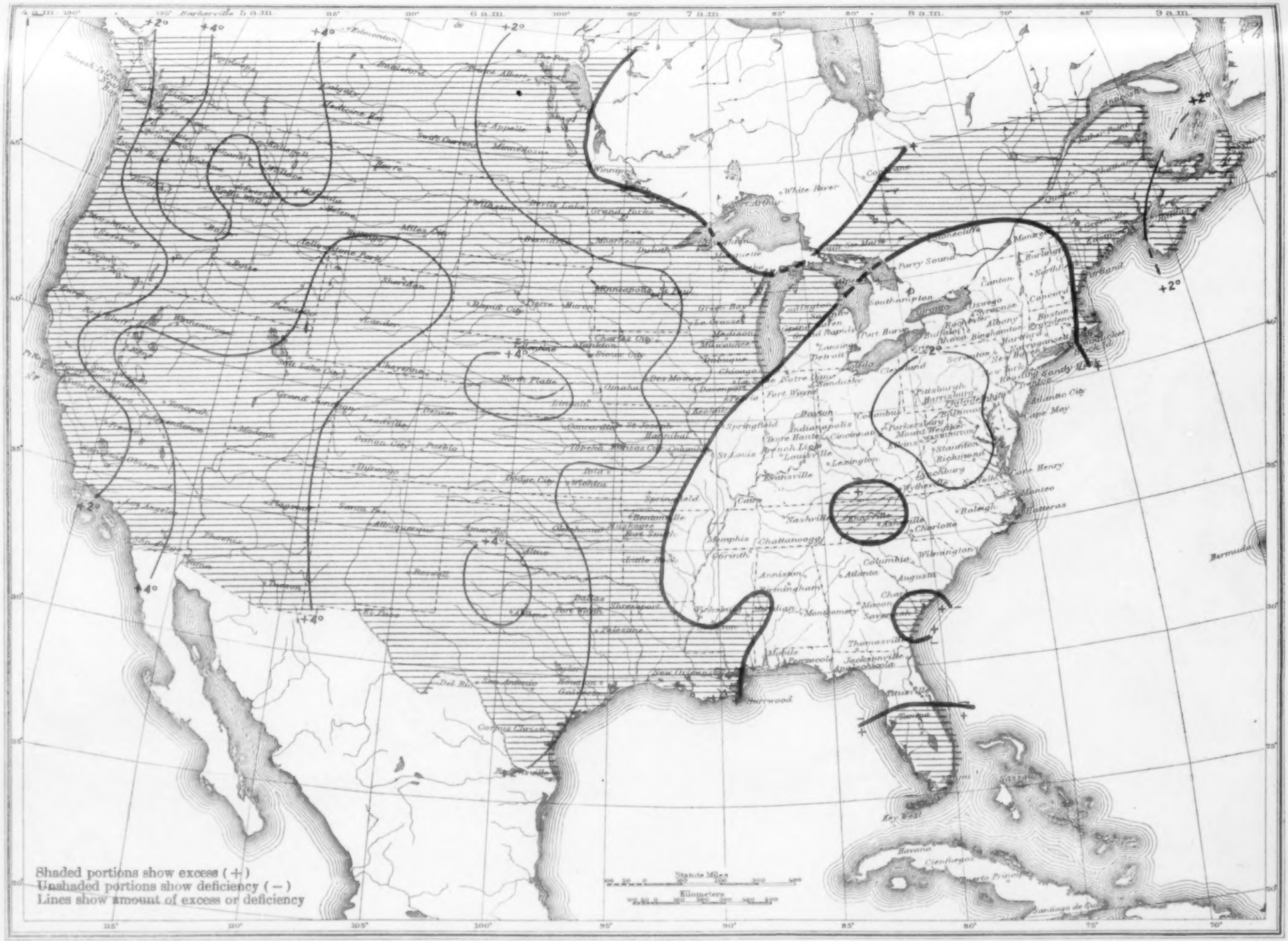
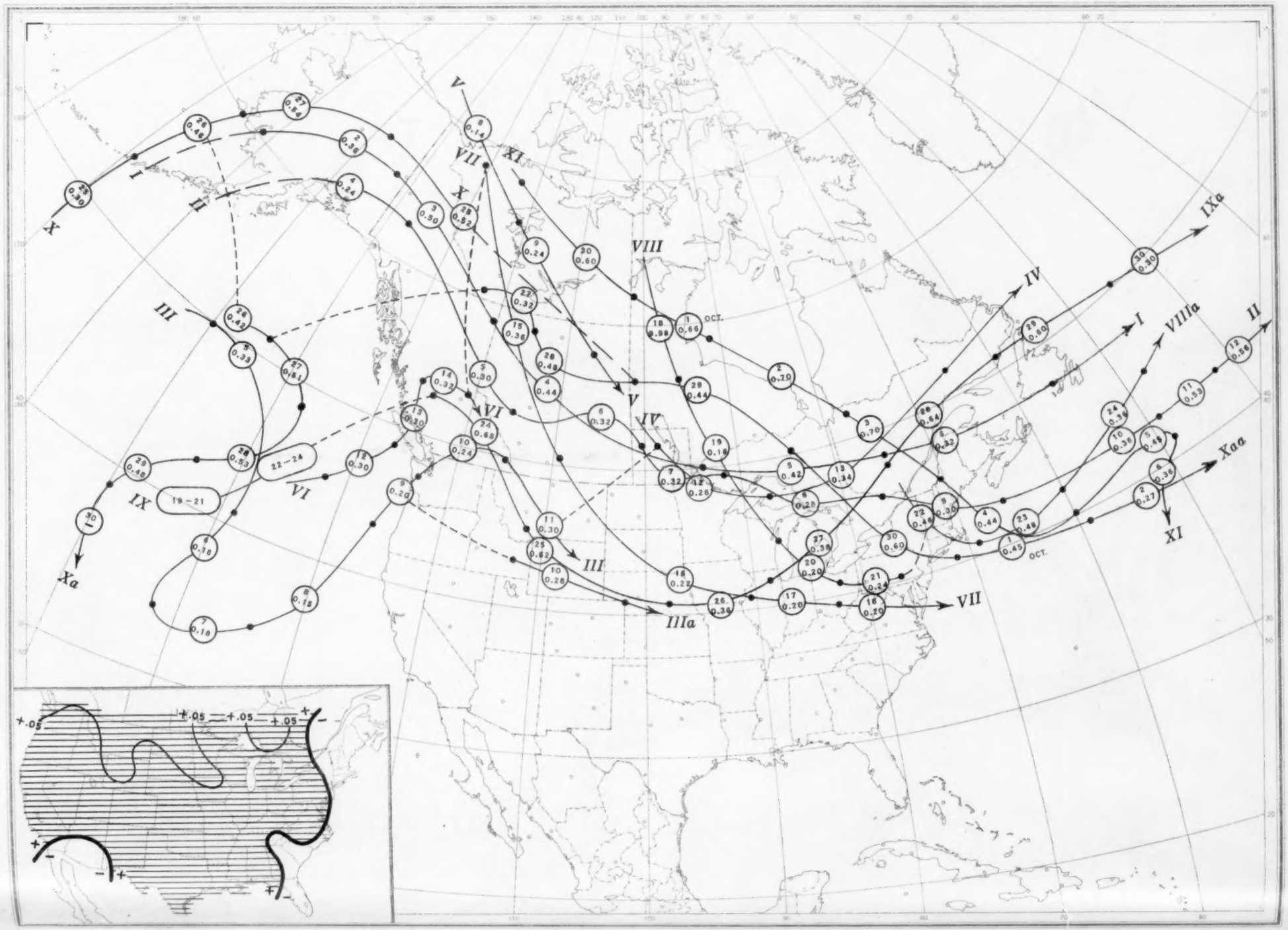

Shaded portions show excess (+)
Unshaded portions show deficiency (−)
Lines show amount of excess or deficiency
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, September 1937. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by W. P. Day)



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

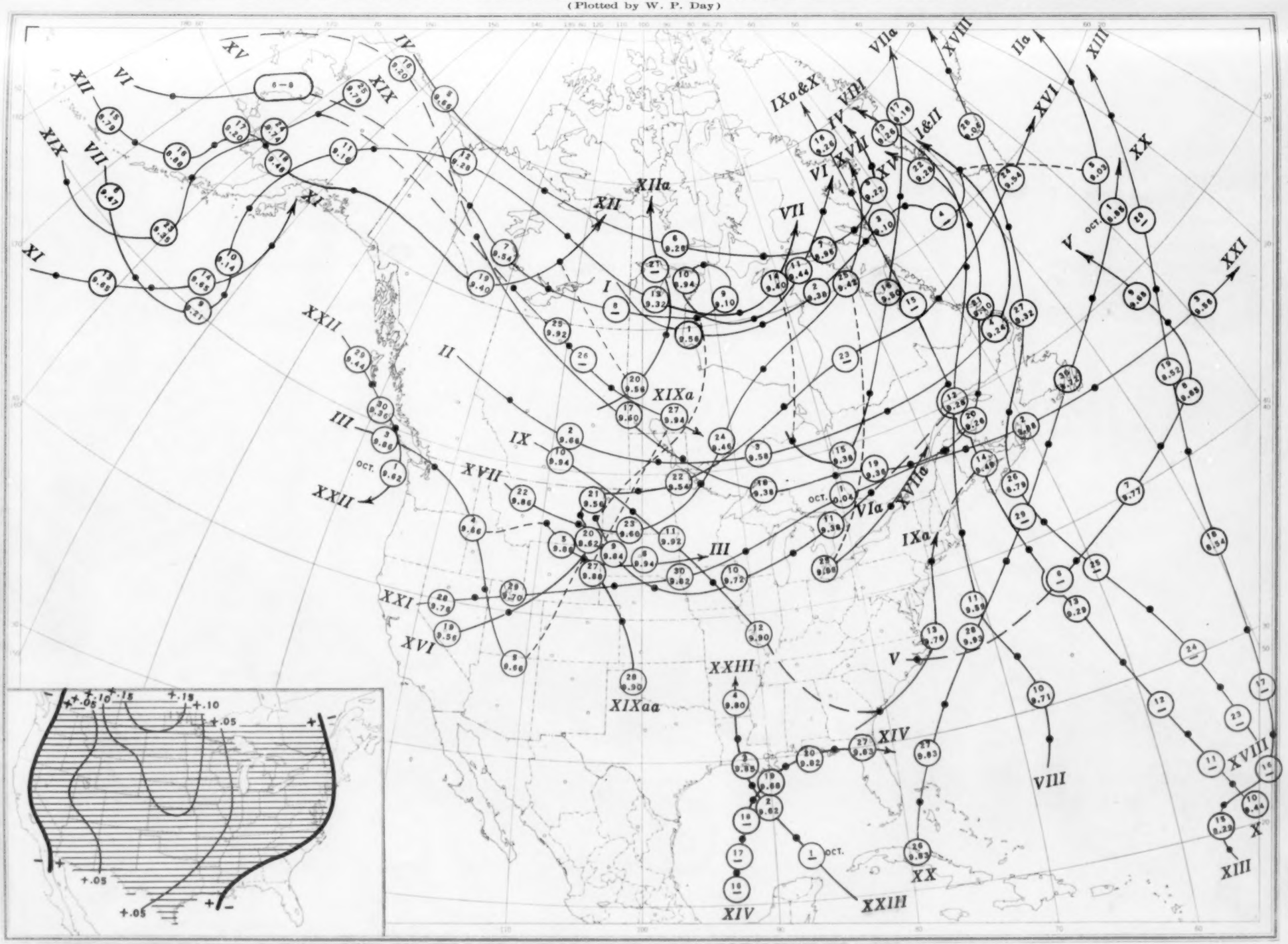
Chart III. Tracks of Centers of Cyclones, September 1937. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by W. P. Day)

Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, September 1937. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by W. P. Day)



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, September 1937

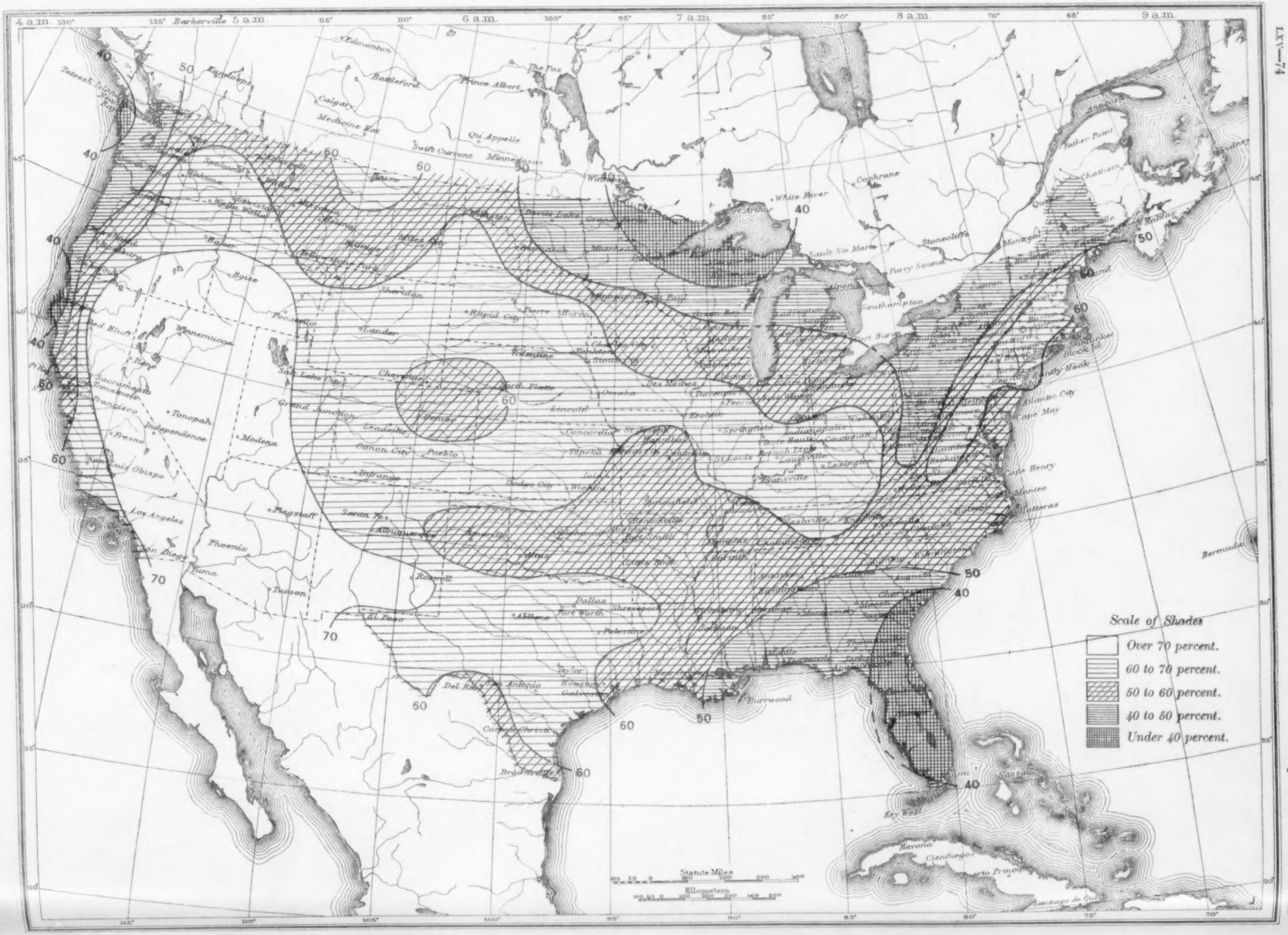


Chart V. Total Precipitation, Inches, September 1937. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, September 1937. (Inset) Departure of Precipitation from Normal

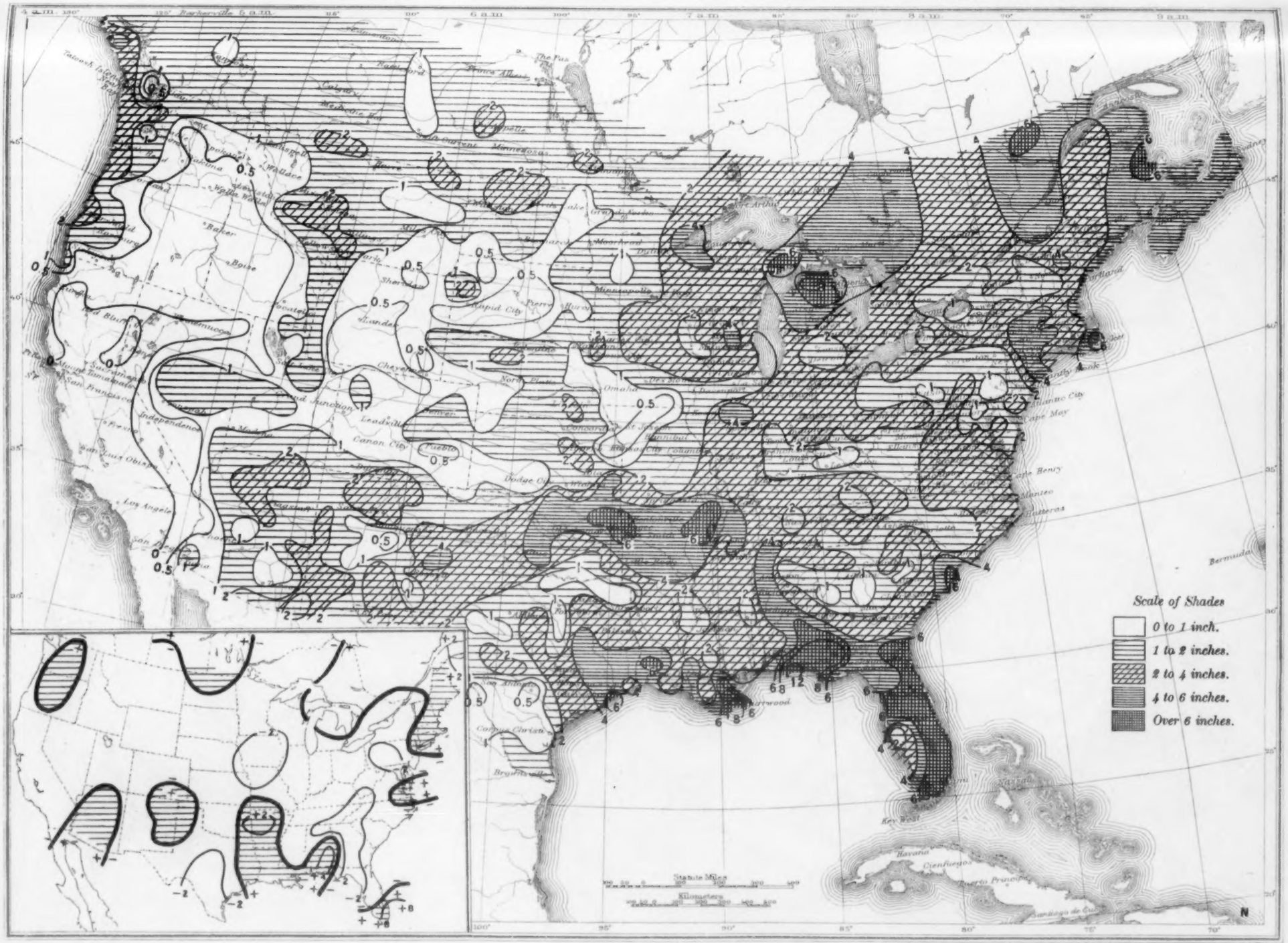


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, September 1937

(Plotted by W. W. Reed)

(Plotted by W. W. Reed)

Weather Map of North Atlantic Ocean, September 18, 1891.

(Plotted from the Weather Bureau Northern Hemisphere Chart.)

Chart IX.—Weather Map of North Atlantic Ocean, September 15, 1937

(Plotted from the Weather Bureau Northern Hemisphere Chart)

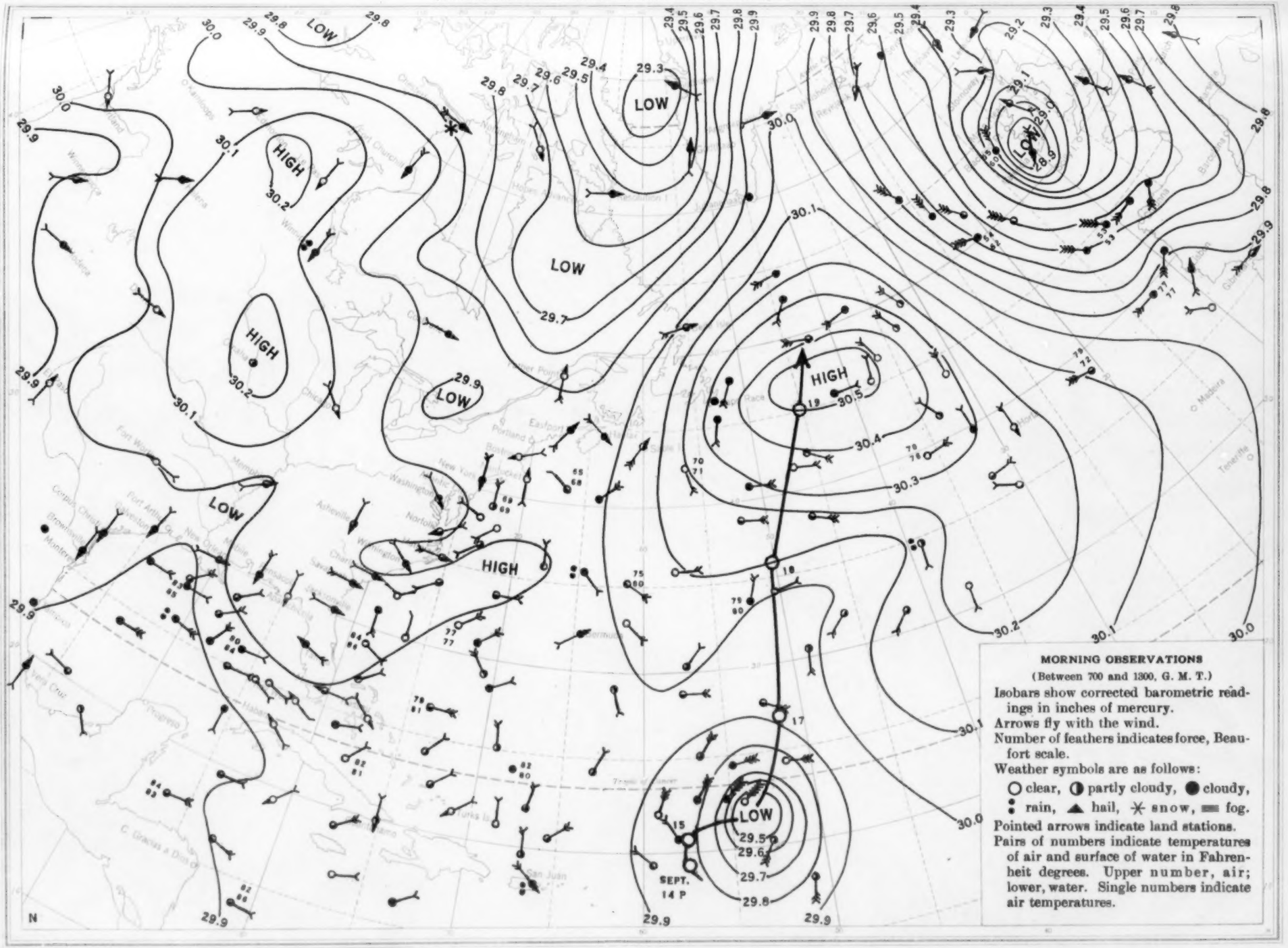
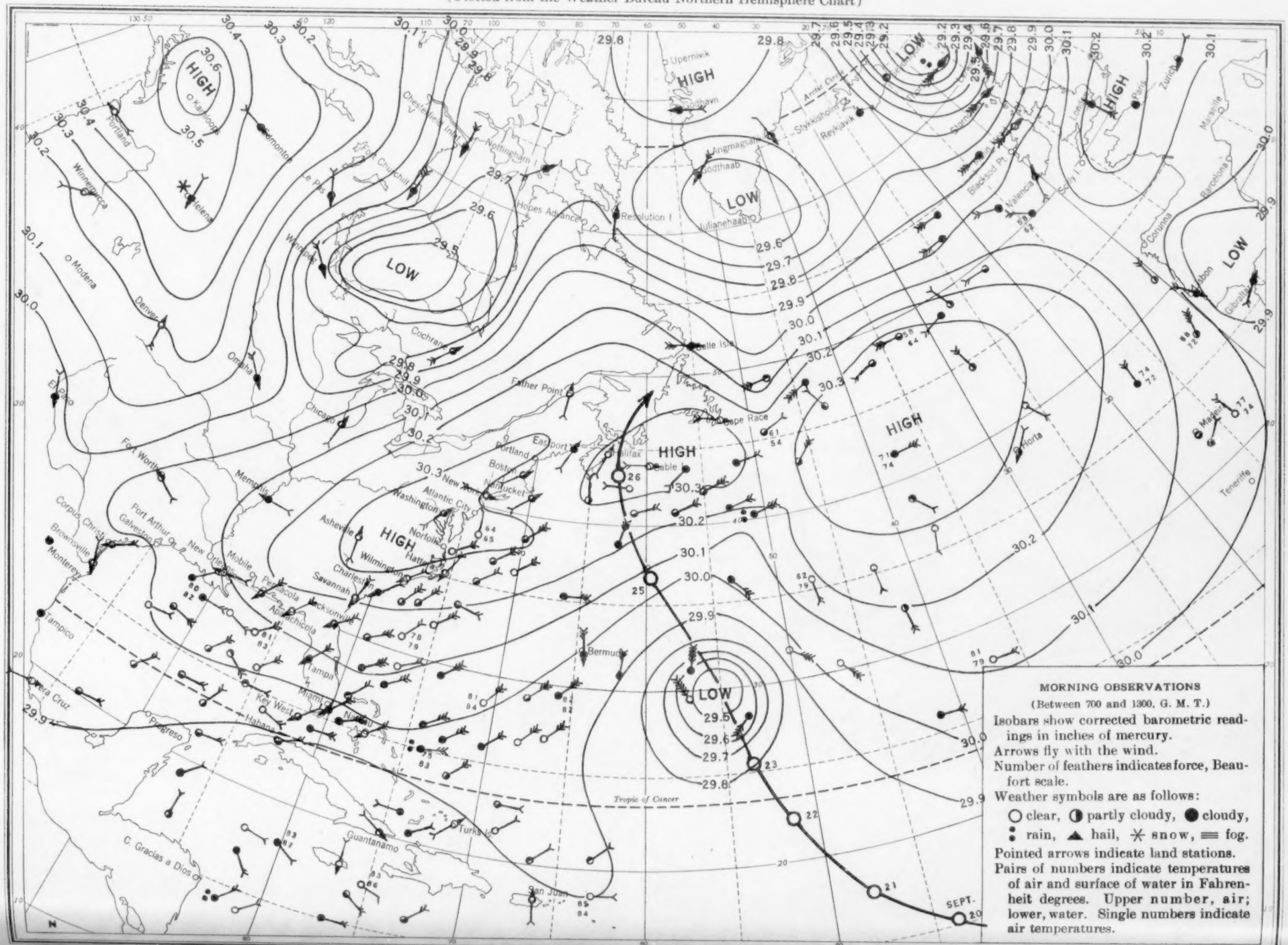


Chart X. Weather Map of North Atlantic Ocean, September 24, 1937

(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicates force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.